SECTION I: USEPA QA/R-5 GROUP A, PROJECT MANAGEMENT

I.A TITLE AND APPROVAL SHEET

Modeling Quality Assurance Project Plan

for

Water Quality Modeling for the Deschutes River, Percival Creek, and Budd Inlet Tributaries TMDLs (Washington)

Contract EP-C-17-046
Task Order 0001

Prepared for:

U.S. Environmental Protection Agency
Region 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101

Prepared by:

Tetra Tech, Inc.
P.O. Box 14409
One Park Drive, Suite 200
Research Triangle Park, NC 27709

February 15, 2019
QAPP 511, Revision 0

This quality assurance project plan (QAPP) has been prepared according to guidance provided in the following documents to ensure that environmental and related data collected, compiled, and/or generated for this project are complete, accurate, and of the type, quantity, and quality required for their intended use:

- *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R-5, EPA/240/B-01/003, U.S. Environmental Protection Agency, Office of Environmental Information, Washington DC, March 2001 [Reissued May 2006])
- *EPA Office of Water Quality Management Plan.* (EPA/821/R-09/001, U.S. Environmental Protection Agency, Office of Water, Washington DC, February 2009)
- *Guidance for Quality Assurance Project Plans for Water Quality Modeling Projects* (EPA 910-R-16-007, U.S. Environmental Protection Agency, Region 10, Office of Environmental Review and Assessment, Seattle, WA, December 2016)

I.B APPROVALS:

Teresa Rafi Task Order Leader Tetra Tech	Date	Susan Lanberg Quality Assurance Officer Tetra Tech	Date
Michelle Schmidt Technical Lead Tetra Tech	Date	Jonathan Butcher, PhD, PH Modeling Quality Control Officer Tetra Tech	Date
Jayne Carlin Task Order Contracting Officer's Representative U.S. Environmental Protection Agency Region 10	Date	Miranda Hodgkiss Technical Lead on TMDL Development U.S. Environmental Protection Agency Region 10	Date
Ben Cope Quality Assurance Coordinator U.S. Environmental Protection Agency Region 10	Date		

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I.D ACRONYMS AND ABBREVIATIONS

7DADMax	seven-day average of daily maximum temperature
CBOD	carbonaceous biochemical oxygen demand
DEM	digital elevation model
DO	dissolved oxygen
EIM	Environmental Information Management System
FLIR	forward looking infrared radiometer
gSSURGO	gridded soil survey geographic database
ICIS	EPA Integrated Compliance Information System
IDL	instrument detection limit
LiDAR	LIght Detection And Ranging
LA	load allocation
MAE	mean absolute error
MDL	method detection limit
MOS	margin of safety
MS4	Municipal Separate Storm Sewer System
NBOD	nitrogenous biochemical oxygen demand
NDVI	Normalized Difference Vegetation Index
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
N-STEPS	Nutrient Scientific Technical Exchange Partnership & Support
NTU	Nephelometric turbidity units
PARIS	Water Quality Permitting and Reporting Information System
PQL	practical quantification limit
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
R^2	correlation coefficient
RMSE	root mean square error

RUSLE	Revised Universal Soil Loss Equation
SDR	sediment delivery ratio
SOD	sediment oxygen demand
TMDL	Total Maximum Daily Load
TOCOR	Task Order Contracting Officer's Representative
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	wasteload allocation

I.E DISTRIBUTION LIST

This document will be distributed to the following U.S. Environmental Protection Agency (USEPA), Washington State Department of Ecology (Ecology), and Tetra Tech staff involved in this project ([REF _Ref489889312 \h]).

Table [SEQ Table * ARABIC]. Water Quality Modeling for Deschutes River, Percival Creek, and Budd Inlet Tributaries TMDLs, QAPP Distribution List

Individual	Phone Number, E-mail Address	Mailing Address
U.S. Environmental Protection Agency Region 10		
Jayne Carlin Task Order Contracting Officer's Representative	206-553-8512 carlin.jayne@epa.gov	USEPA, Region 10 1200 Sixth Avenue, Suite 900 Mail Code OWW-134 Seattle, WA 98101
Miranda Hodgkiss Technical Lead on TMDL Development	206-553-0692 hodgkiss.miranda@epa.gov	USEPA, Region 10 1200 Sixth Avenue, Suite 900 Mail Code OWW-192 Seattle, WA 98101
Christopher Zell Technical Lead on Modeling Analysis	206-553-1353 zell.christopher@epa.gov	USEPA, Region 10 1200 Sixth Avenue, Suite 900 Mail Code OWW-192 Seattle, WA 98101
Ben Cope QA Coordinator	206-553-1442 cope.ben@epa.gov	USEPA, Region 10 1200 Sixth Avenue, Suite 900 Mail Code OERA-140 Seattle, WA 98101
Tetra Tech		
Teresa Rafi Task Order Leader	703-385-2460 teresa.rafi@tetratech.com	Tetra Tech 10306 Eaton Place, Suite 340 Fairfax, VA 22030-2201
Michelle Schmidt Technical Lead	919-485-2081 michelle.schmidt@tetratech.com	Tetra Tech 1 Park Drive, Suite 200 P.O. Box 14409 Research Triangle Park, NC 27709
Susan Lanberg Quality Assurance Officer	703-385-1906 susan.lanberg@tetratech.com	Tetra Tech 10306 Eaton Place, Suite 340 Fairfax, VA 22030
Jonathan Butcher, PhD, PH Modeling Quality Control Officer	919-485-2060 jon.butcher@tetratech.com	Tetra Tech 1 Park Drive, Suite 200 P.O. Box 14409 Research Triangle Park, NC 27709
Brian Pickard, PhD Geospatial Data Steward	919-485-2083 brian.pickard@tetratech.com	Tetra Tech 1 Park Drive, Suite 200 P.O. Box 14409 Research Triangle Park, NC 27709
Sam Sarkar Geospatial Data Steward Quality Control Officer	214-231-4817 sam.sarkar@tetratech.com	Tetra Tech 12655 N. Central Expressway Suite 305 Dallas, TX 75243

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I.F PROJECT/TASK ORGANIZATION

I.F.1 Purpose/Background

The purpose of the project organization is to provide involved parties with a clear understanding of the role that each plays in the project and to provide lines of authority and reporting for the Water Quality Modeling for Deschutes River, Percival Creek, and Budd Inlet Tributaries TMDLs.

I.F.2 Roles and Responsibilities

This section describes the overall organization of the work that will be conducted by Tetra Tech to complete water quality modeling and other technical analyses that will inform the development of refined TMDLs for Deschutes River, Percival Creek, and Budd Inlet Tributaries (Deschutes TMDL). The river and creeks being assessed as part of the Deschutes TMDL are impaired for a variety of constituents including dissolved oxygen (DO), water temperature, pH, fine sediment, and fecal coliform bacteria.

The project management, quality assurance program, and modeling activities are included in this quality assurance project plan (QAPP). Duties and responsibilities of personnel for various aspects of the data collection, model updates, model development and potential calibration, and reporting process are described along with an implementation schedule.

The organizational aspects of a program provide the framework for conducting tasks related to the model update and development. The organizational structure and function can also facilitate project performance and adherence to quality control (QC) procedures and quality assurance (QA) requirements. Key project roles are filled by those persons responsible for ensuring that model setup uses valid data and procedures, and the persons responsible for approving and accepting final products and deliverables. The program organizational chart is presented in [REF _Ref494198553 \h] and includes relationships and lines of communication among all participants and data users. The responsibilities of these persons are described in [REF _Ref343065836 \h].

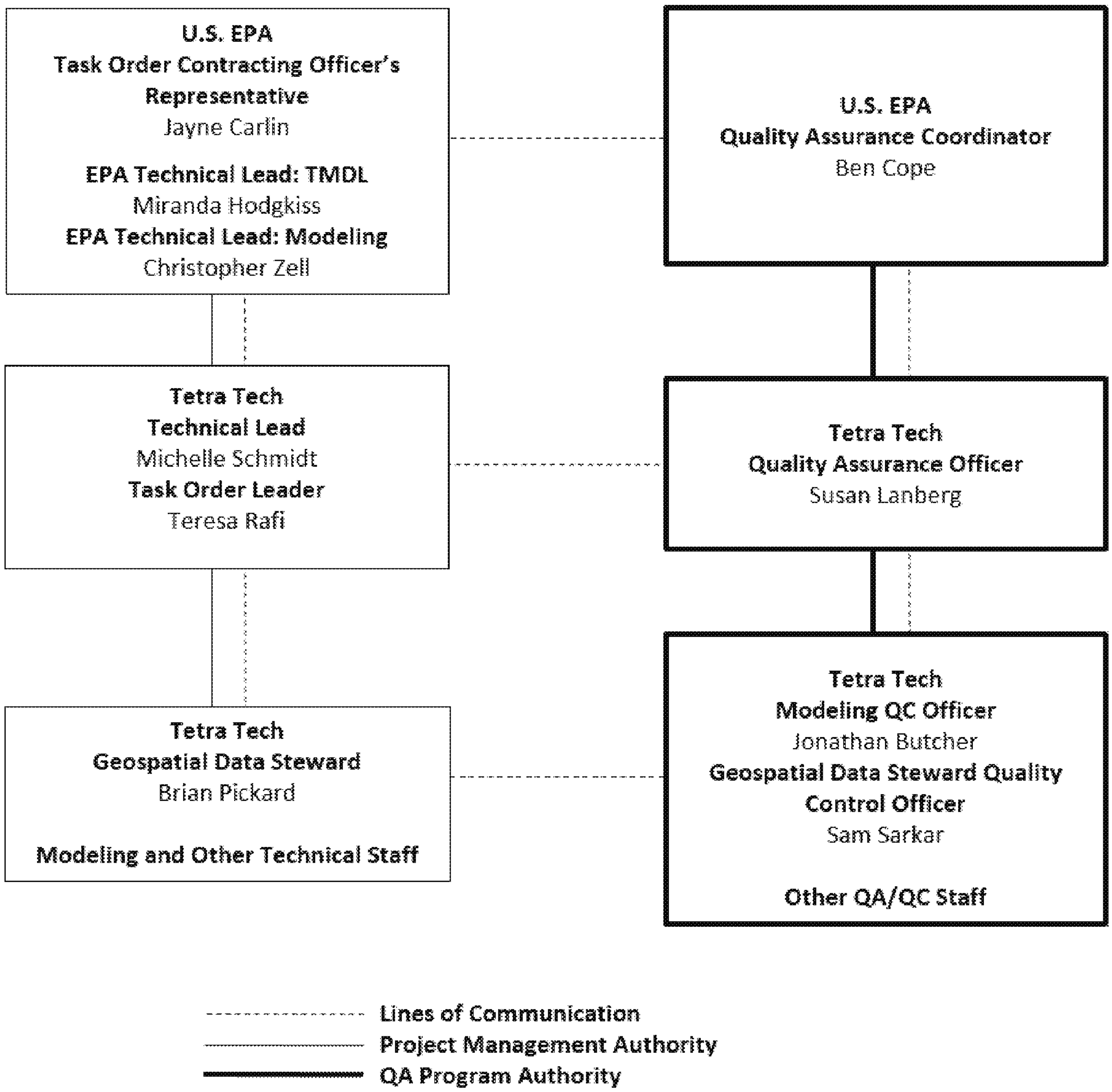


Figure [SEQ Figure * ARABIC]. Project Organization

Note: dashed lines indicate communication only, solid lines indicate authority.

Table [SEQ Table * ARABIC]. Key Personnel Titles and Areas of Responsibility.

TITLE	DESCRIPTION OF DUTIES/RESPONSIBILITIES
USEPA Region 10 Task Order Contracting Officer's Representative	Oversees the technical and administrative aspects of project performance. Issues all technical directives for work and reviews contract requirements prior to initiation of environmental data operations (data collection, management, and any subsequent analyses). Reviews and approves project work plans and quality documentation. Authorized to stop work if work is performed contrary to or in the absence of prescribed controls.
USEPA Region 10 Technical Leads	Responsible for overseeing project planning and ensuring that all appropriate project work planning and quality assurance documents are developed and approved in accordance with USEPA quality policy. Provide oversight for model code updates, data selection/gathering, model evaluation and calibration, and adherence to project objectives. Verify effective implementation of the QAPP requirements at the project level within the scope of their activities. Review and approve project work plans and documentation.
USEPA Region 10 QA Coordinator	Assists in development of the QAPP. Reviews and approves the final QAPP. Provides general QA assistance for the project. Ensures that all project-specific quality system documentation is developed and approved in accordance with USEPA quality policy and contract requirements prior to initiation of modeling. Reviews and approves project work plans and quality documentation.
Tetra Tech Task Order Leader (TOL)	Oversees work performed by Tetra Tech for this project to meet USEPA project requirements. Supervises the assigned project personnel (engineers and support staff) in providing for their efficient utilization by directing their efforts either directly or indirectly on projects. Other specific responsibilities include: coordinate project assignments in establishing priorities and scheduling; ensure the completion of high-quality projects within established budgets and time schedules; provide guidance and technical advice to those assigned to projects by evaluating performance; implement corrective actions and provide professional development to staff; prepare and/or review preparation of project deliverables; and interact with clients, technical reviewers, and agencies to ensure technical quality requirements are met in accordance with contract specifications.
Tetra Tech Quality Assurance Officer	Assists the TOL and Technical Lead in the development of the project QAPP. Reviews and approves the QAPP. Performs general QA oversight for this project. Provides data verification and validation per the QAPP.
Tetra Tech Technical Lead	Leads and supervises model coding, model setup, data selection/gathering, model verification, and calibration work, and is responsible for ensuring that work is carried out and documented in a manner that is consistent with the procedures and quality requirements specified in the QAPP. Reviews model setup and documentation for work conducted by others.
Tetra Tech Geospatial Data Steward	Supervises the geospatial information operations performed for this project and ensure they comply with the EPA *National Geospatial Data Policy* (NGDP; USEPA 2005) and the EPA *National Geospatial Data Policy Procedure for Geospatial Metadata Management* (USEPA 2007). Responsibilities include complying with applicable procedures and standards to meet project objectives and produce documented results or products of known quality. Ensures that geospatial data compiled for this project conform to data exchange protocols, and applicable data standards as defined and maintained by EPA's Office of Environmental Information. Documents geospatial metadata for all spatial data elements compiled into data sets for this project, in accordance with the provisions of FGDC-STD-001-1998, *Content Standard for Digital Geospatial Metadata*.

TITLE	DESCRIPTION OF DUTIES/RESPONSIBILITIES
Tetra Tech Geospatial Data Steward Quality Control Officer	Provides oversight to ensure that geospatial information operations performed for this project comply with the EPA NGDP (USEPA 2005) and the EPA *National Geospatial Data Policy Procedure for Geospatial Metadata Management* (USEPA 2007) described in Section 5.4 of this QAPP. For a particular task, either the Tetra Tech Database and Statistical Lead or the Statistical Analyst who did not perform the original work, will independently review and test the statistical scripts to ensure that they are performing as intended, and yielding desired and accurate outputs.
Tetra Tech QC Officers	A senior technical reviewer, the QC Officer reviews work products and documentation of work conducted by others and responsible for performing evaluations to ensure that QC is maintained throughout the data collection and analysis process. Remains a daily resource for technical, quality, and documentation guidance and direction.

SECTION II: PROBLEM DEFINITION AND MANAGEMENT OBJECTIVES

The Washington Department of Ecology (Ecology) submitted the *Deschutes River, Percival Creek, and Budd Inlet Tributaries Multi-parameter Total Maximum Daily Load Report* (Deschutes TMDL) to the U.S. Environmental Protection Agency (USEPA) on December 17, 2015. The Deschutes TMDL is part of a multi-phase process to address water quality impairments for waters flowing into South Puget Sound. The Deschutes River originates in heavily forested regions of the Bald Hills and flows northward to Capitol Lake (formed in 1951), then to Budd Inlet which connects to Puget Sound. Riverine impairments for dissolved oxygen (DO), temperature, pH, fine sediment, and fecal coliform bacteria were addressed in the submittal. This comprehensive report included individual TMDLs for 73 waterbody-pollutant pairs.

USEPA's Final Action Letter to Ecology (June 29, 2018) presented the agency's decisions regarding the submitted Deschutes TMDLs. The letter states that 26 of the TMDLs (all for temperature) satisfied the statutory and regulatory requirements of § 303(d) of the Clean Water Act and implementing regulations (40 C.F.R. Part 130). Therefore, these 26 TMDLs were approved by USEPA for implementation. Action was not taken by USEPA for 10 of the submitted bacteria TMDLs because these segments were previously delisted from the State's 303(d) list (approved by EPA on July 22, 2016). USEPA's Final Action Letter also states that Ecology submitted revised calculations for 14 bacteria TMDLs on July 17, 2017, which did not allow adequate time for public review as required by 40 C.F.R § 130.7(c)(1)(ii). The revised bacteria TMDLs must undergo public review prior to being eligible for approval by USEPA. Lastly, 23 TMDLs were disapproved by USEPA: three for fecal coliform bacteria, 11 for DO, one for fine sediment, three for pH, and five for temperature. Some were not approved because critical TMDL components were lacking, such as a specified loading capacity to attain applicable water quality standards or defined wasteload allocations (WLAs) and load allocations (LAs). Other TMDLs in the submittal were disapproved because the approach was not protective of downstream waterbodies and uses (e.g., not protective of uses in Budd Inlet, which has a bacteria criterion for shellfish). The fine sediment TMDL for the mainstem Deschutes River was rejected because the technical analysis lacked a linkage between the water quality target and the established loading capacity. The waterbody-pollutant pair TMDLs that were disapproved are summarized in [REF _Ref532294541 \h] and their locations are shown in [REF _Ref532458181 \h][REF _Ref527370983 \h].

Table [SEQ Table * ARABIC]. Deschutes TMDLs Disapproved by USEPA (June 29, 2018 Final Action Letter)

Pollutant	Waterbody	2012 Listing IDs	2010 Listing IDs	Disapproval Rationale
Bacteria	Adams Creek	45462, 45695	45462, 45695	Lacked public review period; TMDLs for the creeks draining directly to Budd Inlet/South Puget Sound were not protective of downstream waters
	Ellis Creek	45480	45480	
	Indian Creek	3758, 74218	3758, 45213, 46410	Lacked public review period
	Mission Creek	45212	45212, 46102	
	Moxlie Creek	3759, 3761	3759, 3761, 45252, 46432	
	Reichel Creek	3763	3763, 45566	
	Schneider Creek	45559	45559	
	Spurgeon Creek	46061	46061	
Dissolved Oxygen	Ayer (Elwanger) Creek	5851	5851	Lacked required TMDL components
	Black Lake Ditch	47761	47761, 47762	
	Deschutes River	10894, 47753, 47754, 47756	10894, 47753, 47754, 47756	Lacked required TMDL components; lacked linkage between water quality target and loading capacity; not protective of downstream waters
	Lake Lawrence Creek	47696	47696	Lacked required TMDL components
	Percival Creek	48085	48085, 48086	Lacked required TMDL components; lacked linkage between water quality target and loading capacity; not protective of downstream waters
	Reichel Creek	47714	47714	Lacked required TMDL components
Fine Sediment	Deschutes River	6232	6232	Lacked linkage between water quality target and loading capacity
pH	Adams Creek	50965	50965	Lacked required TMDL components
	Ayer (Elwanger) Creek	5850	5850	
	Black Lake Ditch	50989	50990	
Temperature	Ayer (Elwanger) Creek	73229		Lacked required TMDL components

Pollutant	Waterbody	2012 Listing IDs	2010 Listing IDs	Disapproval Rationale
	Huckleberry Creek	3757	3757	
	Reichel Creek	48666	48666	
	Tempo Lake Outlet	48696	48696	
	Unnamed Spring to Deschutes River	48713	48923	

The original Deschutes TMDLs developed by Ecology were based on the 2010 303(d) list. Impairments and associated IDs were updated for the 2012 impairment list, therefore, both 2010 and 2012 listing IDs are provided.

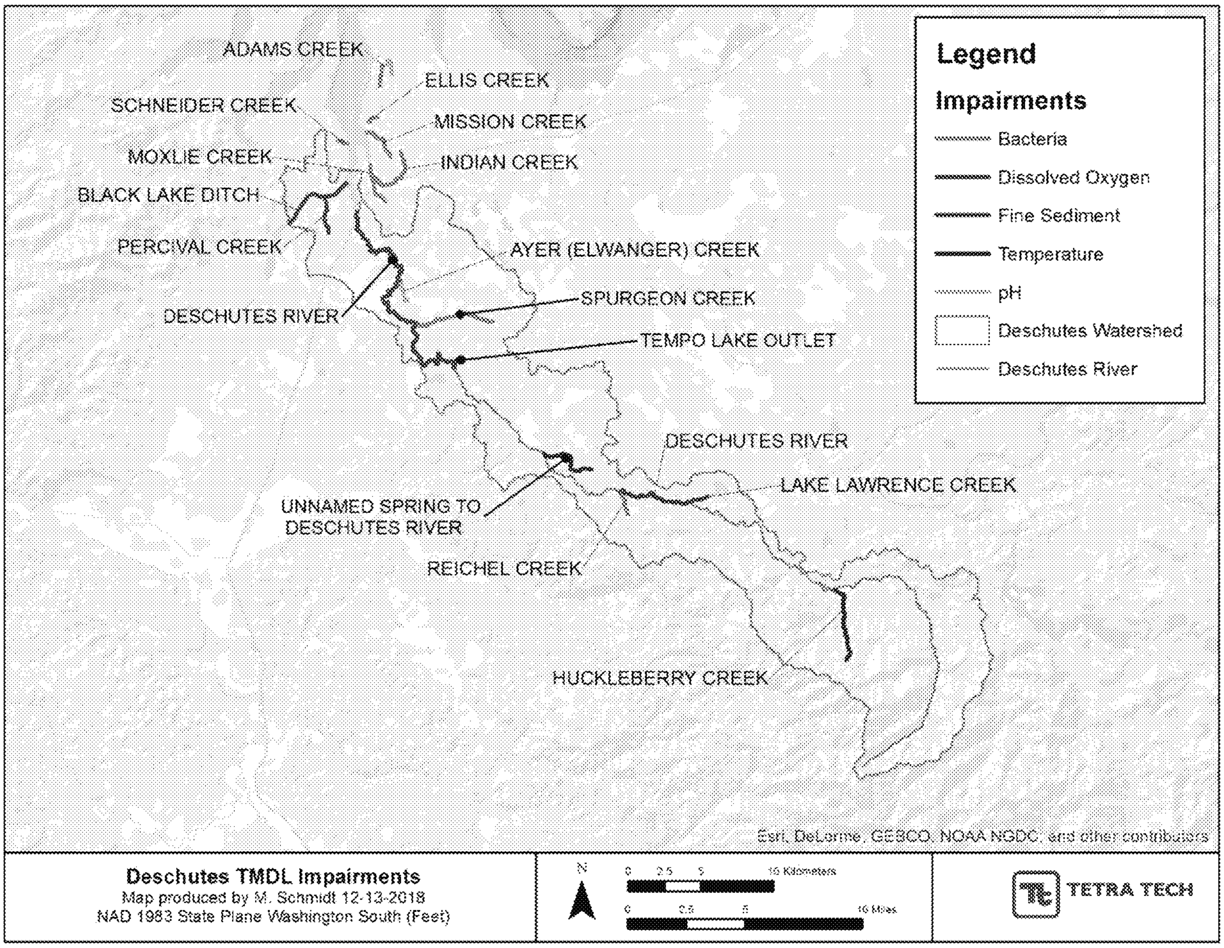


Figure [SEQ Figure * ARABIC]. Impaired Waterbodies in the Deschutes TMDL

Surface water quality is protected and regulated for fresh and marine waters under standards approved by USEPA and adopted by the state of Washington. Waters of the state are assigned designated use classifications, also called beneficial uses, that include aquatic life uses (e.g., core summer salmonid habitat), recreational uses (e.g., primary contact), water supply uses (e.g., domestic water supply), and other miscellaneous uses (e.g., navigation). Definitions of the designated uses for fresh and marine waters are found in WAC 173-201A-600 ([HYPERLINK "http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-600"]) and WAC 173-201A-210 ([HYPERLINK "http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-210"]), respectively. Aquatic life and recreational designated uses of the waterbodies in the Deschutes TMDL that are being reassessed are listed in [REF _Ref532296663 \h].

Surface water conditions must also be protective of downstream designated uses, as discussed in 3(b) of WAC 173-201A-260 ([HYPERLINK "https://apps.leg.wa.gov/wac/default.aspx?cite=173-201A-260"]): *"(3) Procedures for applying water quality criteria. In applying the appropriate water quality criteria for a water body, the department will use the following procedure: (a)… (b) Upstream actions must be conducted in manners that meet downstream water body criteria. Except where and to the extent described otherwise in this chapter, the criteria associated with the most upstream uses designated for a water body are to be applied to headwaters to protect nonfish aquatic species and designated downstream uses."*

In 1(a) of WAC 173-201A-260, consideration of natural conditions in the context of water quality criteria is described: *"(1) Natural and irreversible human conditions. (a) It is recognized that portions of many water bodies cannot meet the assigned criteria due to the natural conditions of the water body. When a water body does not meet its assigned criteria due to natural climatic or landscape attributes, the natural conditions constitute the water quality criteria."*

Table [SEQ Table * ARABIC]. Designated Use (Beneficial Use) Classifications

Waterbody	Designated use	Designated use of downstream waters
Adams Creek	Aquatic: Spawning/Rearing Recreation: Primary Contact	*Budd Inlet/South Puget Sound (Marine):* Aquatic: Excellent Quality Recreation: Primary Contact Other: Shellfish Harvesting
Ayer Creek	Aquatic: Spawning/Rearing Recreation: Primary Contact	Same as Ayer Creek
Black Lake Ditch	Aquatic: Core Summer Habitat Recreation: Extraordinary Primary Contact	Same as Black Lake Ditch
Deschutes River	*Upstream of Offutt Lake* Aquatic: Core Summer Habitat Recreation: Primary Contact *Downstream of Offutt Lake* Aquatic: Spawning/Rearing Recreation: Primary Contact	*Capitol Lake (Freshwater):* Aquatic: Core Summer Habitat Recreation: Extraordinary Primary Contact Water Supply: Domestic, Industrial, Agricultural, Stock *Budd Inlet/South Puget Sound (Marine):* Aquatic: Excellent Quality Recreation: Primary Contact Other: Shellfish Harvesting
Ellis Creek	Aquatic: Spawning/Rearing Recreation: Primary Contact	*Budd Inlet/South Puget Sound (Marine):* Aquatic: Excellent Quality Recreation: Primary Contact Other: Shellfish Harvesting

Waterbody	Designated use	Designated use of downstream waters
Huckleberry Creek	Aquatic: Core Summer Habitat Recreation: Primary Contact	Same as Huckleberry Creek
Indian Creek	Aquatic: Spawning/Rearing Recreation: Primary Contact	Same as Indian Creek
Lake Lawrence	Aquatic: Core Summer Habitat Recreation: Primary Contact	Same as Lake Lawrence
Mission Creek	Aquatic: Spawning/Rearing Recreation: Primary Contact	*Budd Inlet/South Puget Sound (Marine):* Aquatic: Excellent Quality Recreation: Primary Contact Other: Shellfish Harvesting *Inner Budd Inlet (Marine):* Aquatic: Good Quality Recreation: Secondary Contact
Moxlie Creek	Aquatic: Spawning/Rearing Recreation: Primary Contact	*Inner Budd Inlet (Marine):* Aquatic: Good Quality Recreation: Secondary Contact
Percival Creek	Aquatic: Core Summer Habitat Recreation: Extraordinary Primary Contact	*Capitol Lake (Freshwater):* Aquatic: Core Summer Habitat Recreation: Extraordinary Primary Contact Water Supply: Domestic, Industrial, Agricultural, Stock *Budd Inlet/South Puget Sound (Marine):* Aquatic: Excellent Quality Recreation: Primary Contact Other: Shellfish Harvesting
Reichel Creek	Aquatic: Core Summer Habitat Recreation: Primary Contact	Same as Reichel Creek
Schneider Creek	Aquatic: Spawning/Rearing Recreation: Primary Contact	*Inner Budd Inlet (Marine):* Aquatic: Good Quality Recreation: Secondary Contact
Spurgeon Creek	Aquatic: Spawning/Rearing Recreation: Primary Contact	Same as Spurgeon Creek
Tempo Lake Outlet	Aquatic: Spawning/Rearing Recreation: Primary Contact	Same as Tempo Lake Outlet
Unnamed spring to Deschutes River (Listing ID 48923)	Aquatic: Core Summer Habitat Recreation: Primary Contact	Same as unnamed spring to Deschutes River

The designated uses of a water body or water segment determine the applicable surface water quality standards; these standards include both numeric and narrative criteria that are used to identify impairments and inform the development of critical TMDL components (e.g., loading capacity). The original submittal of the Deschutes TMDL was based on surface water quality standards established by the State in December 2006 that were approved by USEPA in February 2008. A revision of the State's surface water quality standards was adopted by Ecology in August 2016 and released in October 2017 (#06-10-091; [HYPERLINK "https://fortress.wa.gov/ecy/publications/summarypages/0610091.html"]). The revision was partially approved by USEPA on November 15, 2016 (https://www.epa.gov/sites/production/files/2017-10/documents/wawqs-letter-11152016.pdf); the revisions that were disapproved pertain to human health criteria and toxics, which are not applicable to TMDLs for the Deschutes River, Percival Creek, and Budd Inlet Tributaries described in this QAPP. Surface water quality standards from this latest revision to the water quality standards will be used to develop loading capacities for the revised TMDLs, as described in the following sections.

II.A BACTERIA

Exposure to harmful waterborne bacteria, pathogens, and viruses can result in serious illness. Fecal coliform bacteria originate from the fecal waste of warm-blooded animals. These bacteria are generally not harmful, but presence of fecal coliform bacteria indicates that other disease-causing organisms associated with fecal waste may be in the water. Because of this, fecal coliform bacteria concentrations are often used as an indicator of human health risk. The State's surface water quality standards specify two statistical measures for assessing bacteria for each recreational class. Both a geometric mean criterion and a top 10 percent of samples criterion must be met for compliance.

For freshwaters, fecal coliform organism levels in waters designated as *Extraordinary Primary Contact* or *Lake Class* must not exceed a geometric mean value of 50 colonies/100 mL. A second component of the standard states that not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value can exceed 100 colonies/100 mL. Fecal coliform organism levels in waters designated as *Primary Contact Recreation* must not exceed a geometric mean value of 100 colonies /100 mL, and not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value can exceed 200 colonies /100 mL. The bacteria water quality standards for fresh waters recommend that the geometric mean is calculated seasonally, preferably with five or more samples for each period.

Bacteria criteria for marine waters are more stringent. The *Primary Contact Recreation* standard, which matches the *Shellfish Harvesting* bacteria criterion, both of which apply to Budd Inlet/South Puget Sound, requires that fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100 mL. In addition, not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value can exceed 43 colonies/100 mL. The *Secondary Contact Recreation* bacteria standard that applies to Inner Budd Inlet is defined in terms of enterococci rather than fecal coliform: enterococci organism levels must not exceed a geometric mean value of 70 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value can exceed 208 colonies/100 mL.

As shown in [REF _Ref532294541 \h], bacteria TMDLs for several creeks, many of which drain directly to Budd Inlet, were disapproved by USEPA. The bacteria TMDLs were not deemed acceptable for a variety of reasons. For all waterbodies except Ellis and Adams Creeks, EPA found the revised TMDLs submitted in 2017 technically acceptable; however, they need to undergo a public review period. For Ellis and Adams Creeks, the shellfish criterion for Budd Inlet/South Puget Sound is more stringent than the primary contact standard applicable to the creeks. Thus, TMDLs proposed for those creeks may not ensure protection of downstream water quality. Mission Creek discharges on the border of the southern-most part of Budd Inlet/South Puget Sound and northern-most part of Inner Budd Inlet; updates to the Mission Creek bacteria TMDL must also protect these downstream marine waters. Another weakness of the TMDLs was that allocations were not assigned for individual stormwater permittees. The revised TMDLs will also address these concerns.

II.B WATER TEMPERATURE

Water temperature affects the behavior and survival of fish and other aquatic species and is an important factor affecting dissolved oxygen concentrations. Water temperature standards for Washington are established based on the most sensitive species that the waterbody supports. Thus, the aquatic life water temperature criterion for a waterbody supporting cold-water species is generally defined as the highest allowable 7-day average of daily maximum temperature (7DADMax). To ensure that a waterbody provides a suitable habitat, water temperature criteria are often defined by critical life-stages, such as spawning and rearing of juvenile fish.

Temperature TMDLs are being reassessed for five waterbodies. Ayer Creek and Tempo Lake Outlet support salmonid spawning, rearing, and migration and the applicable 7DADMax standard is 17.5 °C (activity period September 16 – June 14). The 7DADMax standard is 16 °C for Huckleberry Creek, Reichel Creek, and an unnamed Spring to Deschutes River, which provide core summer salmonid habitat (activity period June 15 – September 15). Water temperatures are not to exceed the 7DADMax standards more than once every 10 years on average. In addition to the 7DADMax criterion for a waterbody, human activities are prohibited from cumulatively causing more than a 0.3 °C increase in water temperature when a waterbody is naturally warmer than the 7DADMax standard.

II.C DISSOLVED OXYGEN

Fish and other aquatic species rely on dissolved oxygen (DO) in water to survive, and low DO can be a significant impairment. Low levels of DO in fresh water can be due to excessive algae, which produce oxygen through photosynthesis during daylight hours, but uptake oxygen for respiration during nighttime hours, resulting in large diurnal DO fluctuations. Warm waterbodies may also exhibit low DO levels because warmer temperatures decrease oxygen solubility in water. Slow moving, or stagnant, waters with slow rates of reaeration may also exhibit low DO.

Similar to water temperature, the aquatic life DO criteria are defined by the most sensitive species supported by the waterbody and differ according to life-stage. DO TMDLs are being developed for multiple waterbodies in the Deschutes River Basin that have been assigned aquatic life designated uses of either salmonid spawning, rearing, and migration or core summer salmonid habitat. The lowest 1-day minimum DO concentration defined for salmonid spawning, rearing, and migration is 8.0 mg/L (activity period: September 16 – June 14). The lowest 1-day minimum DO concentration for core summer salmonid habitat segments is 9.5 mg/L (activity period: June 15 – September 15). DO is not to fall below the specified concentration at a frequency of more than once every ten years on average. Human activity may not reduce DO concentrations by more than 0.2 mg/L if natural conditions result in DO concentrations lower than the criterion.

There is not a minimum numeric DO criterion for Lake Class waters; however, a narrative criterion specifies that anthropogenic activities must not cumulatively decrease DO concentrations by more than 0.2 mg/L from that of natural conditions. The lowest 1-day minimum DO standards for marine waters designated as *Excellent Quality* (applies to Budd Inlet/South Puget Sound) and *Good Quality* (applies to Inner Budd Inlet) are 6.0 mg/L and 5.0 mg/L, respectively.

II.D pH

Washington adopted aquatic life pH criteria for fresh water because excessive deviations from neutral pH (7.0) can cause cognitive and physiological damage to fish (e.g., inhibit predator detection, stunt the growth of juvenile fish), and can sometimes be lethal. In addition, overly acidic or alkaline waters can facilitate chemical reactions and alter the toxicity of other substances. In some cases, abnormal pH is related to natural geology or waste discharges; however, it is more common to find pH deviations resulting from excess algal growth that depletes carbon dioxide during daytime photosynthesis (raising pH) and increases carbon dioxide during nighttime respiration (lowering pH). For core summer salmonid habitat streams and salmonid spawning, rearing, and migration streams the target pH range is 6.5 to 8.5 (expressed as the negative logarithm of the hydrogen ion concentration). Human-caused variation is to be less than 0.2 units for core summer salmonid habitat segments, and less than 0.5 units for salmonid spawning, rearing, and migration segments.

II.E FINE SEDIMENT

Open space between the rocks of streambeds provides young fish with habitat to hide from predators and provides a place to graze for food. Fine sediment that accumulates and clogs the spaces between cobbles and boulders can inhibit the survival of young fish. Adult salmon build spawning nests (redds) in the riffle of a gravel streambed and deposition of fine sediment can block oxygen flow to the nest and prevent successful hatching. Numeric targets have not been formally established for fine sediment in Washington; however, fine sediment accumulation that degrades the habitat of sensitive species is covered by narrative standard WAC 173-201A-260(2), which states:

> *"Toxic, radioactive, or deleterious material concentrations must be below those which have the potential, either singularly or cumulatively, to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health."*

The Washington Forest Practices Board (1997) classifies streams with less than 12 percent fine sediment in gravels as of good habitat quality, 12 to 17 percent as of fair quality, and greater than 17 percent as of poor habitat quality. Past field studies (e.g., by Konovsky and Puhn, 2005) found excessive fine sediment levels in the streambed of the Deschutes River for which a TMDL is being developed.

Fine sediment loading is also associated with elevated turbidity (decreased water clarity). Washington has adopted numeric aquatic life turbidity criteria for fresh water. The same standard applies to designated uses of core summer habitat and spawning, rearing, and migration. When background turbidity is 50 nephelometric turbidity units (NTU) or less, the turbidity shall not exceed 5 NTU over background. When background turbidity is more than 50 NTU there cannot be more than a 10% increase in NTU. While the Deschutes River has not been listed as impaired for turbidity, it will be appropriate to also evaluate compliance with the turbidity criterion in the TMDL for fine sediment.

SECTION III: CONCEPTUAL MODELS: KEY PROCESSES AND VARIABLES

Water quality impairments to be addressed in the Deschutes River and tributaries are for bacteria, water temperature, dissolved oxygen (DO), pH, and fine sediment. Conceptual models for each of these types of impairment describe the linkage between the impaired endpoint and the ultimate sources of stressors, along with a description of the key modifying processes and parameters.

Bacteria:

- Models/Tools: The Load Duration Curve method will be applied for the bacteria impairments, as described in Section IV.C.
- Endpoint: Water quality criteria for concentrations of fecal coliform bacteria and/or enterococci, depending on the designated use of the waterbody segment and the downstream segment, if the latter is more stringent.
- Stressor sources include all sources of fecal matter load, including onsite wastewater treatment systems, urban runoff, livestock, pets, and wildlife.
- Key modifying processes include washoff from and die-off on the land surface, advective transport in streamflow, sorption and settling, and die-off or removal in the water column. The die-off rates on the land and in the water column are affected by temperature, exposure to ultraviolet radiation, and salinity.
- Key parameters in a Load Duration Curve analysis are paired flow volumes and bacteria concentrations. Flow records are unavailable for the bacteria impaired creeks; therefore, flow records from a long-term gage operated by USGS will be scaled based on relative drainage area to determine a representative flow for the impairment. The relative drainage area ratio is a key parameter. Bacteria die-off instream is considered negligible for the Load Duration Curve analysis, which ensures a high level of confidence that the target loading capacity will achieve the most stringent applicable bacteria criterion.

Water Temperature:

- Models/Tools: Segments impaired for temperature will be evaluated with a riparian shade model (Shade.xls with inputs derived from TTools an ArcGIS extension) and a critical-condition receiving water model (QUAL2Kw), as described in Section IVB.1.2.
- Endpoint: Water quality criteria for acceptable maximum water temperatures, expressed as 7DADMax temperatures based on designated use of the waterbody segment or as a maximum allowable human-caused deviation from the 7DADMax under natural conditions when natural conditions are expected to exceed the applicable criterion 7DADMax.

- Stressor sources include shortwave solar radiation, longwave radiation exchange between the water column and atmosphere, heat transport from conduction/convection, heat loss from evaporation, , net heat exchange with the bed, heat content of surface and subsurface inflows, channel modification, water diversion, shade loss, and heat content of wastewater discharges.
- Key modifying processes include extent of riparian and topographic shade (which affects both shortwave and longwave radiation processes), bed thickness and conductivity, channel velocity and width/depth ratios, and the fraction of flow that is hyporheic.
- Key parameters in a receiving water model are those that describe the heat transport modifications due to shade, those describing heat exchange between the waterbody and the atmosphere, hyporheic flow fraction, and bed thickness and thermal conductivity.

Dissolved Oxygen:

- Models/Tools: Segments impaired for dissolved oxygen will be evaluated with a riparian shade model (Shade.xls with inputs derived from TTools an ArcGIS extension) and a critical-condition receiving water model (QUAL2Kw), as described in Sections IVB.1.1 and IVB.1.2.
- Endpoint: Water quality criteria that specify the acceptable range of DO concentrations for the designated use of the waterbody segment (and the downstream segment, if the latter is more stringent.)
- Stressor sources include allochthonous and autochthonous loads of oxidizable organic carbon (biomass, often expressed as carbonaceous biochemical oxygen demand or CBOD), sources of reduced nitrogen (i.e., nitrogenous BOD or NBOD), other compounds subject to bacterial oxidation (e.g., reduced iron oxidation by iron bacteria), oxygen uptake due to nighttime respiration of phytoplankton and aquatic plants, sediment oxygen demand (SOD), and reduced DO in surface and subsurface inflows. Sources of nutrient load are a key factor in the modifying processes described below.
- Key modifying processes include the decay of CBOD and NBOD, oxygen demand exerted by SOD, and the growth, respiration, death, and decay cycles of phytoplankton, benthic algae, and aquatic plants. All these processes are subject to variation with temperature, so all modifying processes and parameters that affect water temperature are also applicable to dissolved oxygen. Growth and respiration of phytoplankton, benthic algae, and aquatic plants also depends on the availability of nutrients and light. Light availability in the water column in turn depends on channel geometry and the presence of suspended sediment or other sources of turbidity.
- Key parameters in a receiving water model include rates of CBOD, NBOD, and SOD exertion. Algal respiration and decay of dead algal biomass is anticipated to be an important source of DO depletion in the Deschutes, and maximum algal growth rates, algal death and respiration rates, and Michaelis-Menten half-saturation constants that

describe the relationship between inorganic N and P concentrations and algal growth are important, as are parameters describing the relationship between light availability and algal growth rates. In systems where DO is partially controlled by nutrient availability nutrient loads from point and diffusive sources, chemical transformation rates for inorganic constituents (e.g., nitrification and denitrification), dissolution and setting rates for detritus and organic constituents will also be key parameters.

pH:

- Models/Tools: Segments impaired for pH will be evaluated with a riparian shade model (Shade.xls with inputs derived from TTools an ArcGIS extension) and a critical-condition receiving water model (QUAL2Kw), as described in Section IVB.1.2.
- Endpoint: Water quality criteria that specify the acceptable range of pH for the designated use of the waterbody segment (and the downstream segment, if the latter is more stringent.)
- Stressor sources include loads of oxygen-demanding constituents that promote growth of phytoplankton and aquatic plants. During daylight hours, the plants photosynthesize, producing oxygen (O_2), removing carbon dioxide (CO_2) and bicarbonate ions (HCO_3^-), increasing instream hydroxide (OH-) and pH. During nighttime hours, plants respire, producing carbon dioxide (CO_2) and decreasing instream hydroxide (OH-) and pH. Other potential pH stressor sources include rainwater (e.g., acid rain), site geology and lithology, low stream alkalinity (ability to resist changes in pH), inorganic carbon availability, and industrial and domestic effluents.
- Key modifying processes include instream chemical transformations (e.g., nitrification) and the growth and respiration cycles of phytoplankton, benthic algae, and aquatic plants. These processes are subject to variation with temperature, so all modifying processes and parameters that affect water temperature are also applicable to pH. Growth and respiration of phytoplankton, benthic algae, and aquatic plants also depends on the availability of nutrients and light. Light availability in the water column in turn depends on channel geometry and the presence of suspended sediment or other sources of turbidity.
- Key parameters in a receiving water model include those that impact total organic carbon and alkalinity through chemical, physical or biological processes. Algal growth is anticipated to be an important source of pH fluctuation, and maximum algal growth rates, algal death and respiration rates, and Michaelis-Menten half-saturation constants that describe the relationship between inorganic N and P concentrations and algal growth are important, as are parameters describing the relationship between light availability and algal growth rates.

Fine Sediment:

- Models/Tools: Sediment loads from sheet and rill erosion will be evaluated with the Revised Universal Soil Loss Equation method and paired with past studies that quantified sediment loads from bank erosion, landslides, and unpaved roads (see Section IV.B.2).

- Endpoint: For fine sediment the primary endpoint is the maximum percent fines in spawning gravels consistent with a healthy fish population established in the Timber Fish and Wildlife Watershed Analysis Manual (Washington Forest Practices Board, 1997; Roberts et al., 2012). Water column turbidity is also an important endpoint.
- Stressor sources include upland sediment loads associated with landslides, road erosion, and sheet and rill erosion of pervious land surfaces (primarily forest and agricultural lands upstream of the impaired segment). Additional instream sediment loads are derived from scour and degradation of channel banks and beds.
- Key modifying processes include the overland transport of sediment to streams, and instream scour and deposition processes. Sorting of fine sediments from total sediment load is an important link in the causal chain of impairment.
- Key parameters include those that describe upland sediment detachment and transport to streams, the fraction of delivered total sediment load that is fines, parameters controlling bank scour, and parameters that determine sediment setting rates.

The initial conceptual models described above will be developed in greater detail and presented in graphical form as part of this project.

SECTION IV: TECHNICAL APPROACH

IV.A OVERVIEW

Tetra Tech has been contracted by USEPA Region 10 under Task Order 0001 of Contract EP-C-17-046 to conduct water quality modeling and complete technical analyses that will support the development of revised TMDLs for all waterbody-pollutant pairs in the Deschutes River, Percival Creek, and Budd Inlet tributary watersheds that were not approved by USEPA ([REF _Ref532294541 \h * MERGEFORMAT]). The work will build upon existing predictive models, develop new models for select waterbodies, make substantial improvements to source characterization, incorporate recently collected monitoring data, and provide results to support the development of critical components of the TMDLs. Modeling efforts for the Deschutes TMDLs will also contribute towards the evaluation of the conditions needed to protect downstream fresh and marine waters, which may be subject to different surface water quality regulations. Assessments that aim to evaluate the restored conditions needed in the impaired rivers and creeks to ensure protection of downstream water quality are described in the technical approach section, Section IV. Furthermore, Ecology will be simultaneously developing a TMDL for the downstream Budd Inlet Ex. 5 Deliberative Process (DP) USEPA will facilitate coordination of work on the Deschutes TMDL with work on the Budd Inlet TMDL, especially with respect to modeling.

IV.B WATER QUALITY MODELS FOR TEMPERATURE, DO, PH, AND FINE SEDIMENT

A variety of modeling platforms and methodologies will be used to study pollutant stressors and predict instream responses of the impaired waterbodies. In its work on the Deschutes River TMDLs, Ecology selected QUAL2Kw as the receiving water model. EPA believes QUAL2Kw remains an appropriate tool and will be able to save additional resources by using it in developing these revised TMDLs. Thus, for this project it is not necessary to evaluate other candidate models. In addition to QUAL2Kw, Ecology used other tools, such as TTools and the Shade model, to support the QUAL2Kw application. EPA believes these tools remain useful, and they will be used for these TMDL revisions as well.

Potential modeling approaches for the fine sediment TMDL were evaluated. Previous analyses (Raines, 2007) assessed several key sources of sediment in the Deschutes River watershed including bank erosion (hillslope and glacial terraces), landslides, and unpaved roads. However, loads from sheet and rill erosion have not been quantified for the impairment. Sediment loads due to sheet and rill erosion will be assessed in this effort and paired with past studies of bank erosion, landslides, and unpaved roads for the fine sediment TMDL. Furthermore, the linkage between loading capacity and the fine sediment target will be established.

USEPA's *Protocol for Developing Sediment TMDLs* provides several potential options for assessing sources of sediment and linking these sources to water quality targets (USEPA, 1999). One option is the use of process-based or mechanistic models, which can be used to identify the change in erosion and sedimentation processes needed restore water quality. The Soil and Water Assessment Tool (SWAT; Neitsch et al., 2011) and Hydrologic Simulation Program – FORTRAN (HSPF; Bicknell et al., 1997) are two examples of modeling programs that can be used to simulate continuous hydrology and sediment at the watershed-scale. However, development, calibration, and validation of a mechanistic model for the Deschutes River watershed is not feasible due to time constraints on completing the TMDL. Empirical linkage models are also acceptable. This method is more suitable for suspended sediment TMDLs where source loads can be paired with flows to derive instream concentrations. Available water column sediment data (e.g., total suspended sediment) is insufficient to apply this approach for the impaired segment, and a linkage between water column sediment and fines in gravel would remain uncertain.

The U.S. Department of Agriculture Agricultural Research Service's Revised Universal Soil Loss Equation (RUSLE; Renard, 1997) predicts average annual soil loss due to raindrop impact and surface runoff. RUSLE can be implemented using spatially explicit (grid-based) parameter inputs building on equations and recommendations found in the RUSLE user's guide. Recent research has developed geographical information system (GIS) techniques for determining sediment connectivity on landscapes (Borselli et al., 2008) and the method has been extended to provide parametric landscape-based estimates of sediment delivery ratios that can be used with grid-based applications of RUSLE (e.g., Vigiak et al., 2012). Given the study objectives, time constraint, and minimal monitoring information, the gridded Revised Universal Soil Loss Equation (RUSLE) method will be applied in conjunction with the sediment delivery ratio method of Vigiak et al. to approximate sheet and rill erosion loads delivered to impaired segment.

A summary of models used for the revision of the Deschutes TMDLs is presented in [REF _Ref532301868 \h]. The descriptions of the modeling approaches to be implemented are described in the following subsections by impairment type.

Table [SEQ Table * ARABIC]. Summary of Models

Impairments	Model
Temperature, pH, and DO	TTools ArcGIS Extension; Shade Model (http://www.ecy.wa.gov/programs/eap/models.html); QUAL2Kw (Pelletier and Chapra, 2006)
Fine sediment	Revised Universal Soil Loss Equation (RUSLE) method (Renard, 1997); Turbidity regression (Packman et al., 1999)

IV.B.1 Temperature, pH, and Dissolved Oxygen Impairments

Modeling support for the water temperature, DO, and pH TMDLs will include applications of a riparian shade model (Shade model) and riverine water quality model (QUAL2Kw). It is anticipated that the initial Technical Direction (TD) for the modeling work will include the development of a pilot QUAL2Kw model for one of the impaired tributary streams. Results from the pilot tributary model will be supplied to USEPA for review and discuss with Tetra Tech. If USEPA decides to complete modeling for the remaining tributaries, or a subset of the tributaries, the TD will be revised. However, the QAPP will not require revision because the approach that would be used to develop, calibrate, and apply QUAL2Kw models for the tributaries is documented in this QAPP.

The Shade model was developed by Oregon Department of Environmental Quality (ODEQ) and can be used to evaluate solar radiation along a stream using specific geographic information system (GIS)-based data derived with the TTools ArcGIS extension. TTools uses input coverages and grids to develop vegetation and topography data perpendicular to the stream channel, and samples longitudinal stream channel characteristics such as the near-stream disturbance zone (NSDZ) and elevation. TTools can sample spatial data within the riparian zone including vegetation height and land use classification depending on available remote sensing data. Typically, these include LIght Detection And Ranging (LiDAR) outputs, digital elevation models (DEMs), riparian vegetation digitized from aerial imagery (digital orthophoto quadrangles and rectified aerial photos), and FLIR (forward looking infrared radiometer) thermal imaging temperature data.

Ecology's Shade model (Shade.xls—a Microsoft Excel spreadsheet available at [HYPERLINK "http://www.ecy.wa.gov/programs/eap/models.html"]) quantifies potential daily solar load and generates percent effective shade. Effective shade is the fraction of shortwave solar radiation that does not reach the stream surface because vegetative cover and topography intercept it. Effective shade is influenced by latitude/longitude, time of year, stream geometry, topography, and vegetative buffer characteristics, such as height, width, overhang, and density. Data inputs for a Shade model are readily available (e.g., aerial imagery; DEMs), and additional data (e.g., vegetation height from first and last returns, overhang) can be estimated from LiDAR and other data sources. TTools output serves as input for the Shade model, which is then used to generate longitudinal effective shade profiles. Reach-averaged integrated hourly effective shade (i.e., the fraction of potential solar radiation blocked by topography and vegetation) serves as an input into an accompanying QUAL2Kw model.

The modeling framework of QUAL2K was originally developed at Tufts University as a one-dimensional river water quality model capable of simulating steady-state hydraulics, and diel heat budget and water quality kinetics. Ecology updated the original model to QUAL2Kw, which is capable of simulating dynamic hydraulics with continuous simulation of variable boundary conditions (Pelletier and Chapra, 2006). QUAL2Kw is a one-dimensional model that simulates temperature, nutrients, dissolved oxygen, pH, phytoplankton, and bottom algae. The model also simulates sediment diagenesis and allows for the incorporation of hyporheic flow through the riverbed. The QUAL2Kw model allows for user-defined inputs of heat and constituent mass inputs for point and nonpoint sources and groundwater.

IVB.1.1 Deschutes River Dissolved Oxygen TMDL

The calibrated Deschutes River QUAL2Kw model that was developed by Ecology to support the previous TMDL submission will be used to update the DO TMDL for the Deschutes River. This update will include developing required components of the TMDL that were previously lacking, quantifying the linkage between water quality targets and loading capacity, and ensure the protection of downstream waters. The steady-state QUAL2Kw model was paired with a riparian Shade model for the Deschutes River and these were applied in the development of the Deschutes River temperature TMDL, which was approved by USEPA.

Achievement of the riparian shade targets for temperature is not sufficient to meet DO standards in the river with the designated use of core summer habitat. An additional contribution to depressed DO is caused by attached and planktonic algal growth and respiration, which is in turn driven by nutrient concentrations, therefore, the DO TMDL must also evaluate potential limits on nutrient loads. Instream targets for nutrients to address DO impairments in the Deschutes River will be assessed through application of the QUAL2Kw model. Stressor response curves will be developed based on simulations of the QUAL2Kw model; these curves will provide information regarding the relationships between stressors (e.g., instream concentrations of nitrogen and phosphorus) and DO in the impaired segments of the river. In addition to nutrients, sensitivity of DO to loads of carbonaceous biochemical oxygen demand (CBOD) and sediment oxygen demand (SOD) will be assessed with the model, and CBOD will be considered as a potential constituent for which to derive daily loading capacities. Instream targets for nutrients will be evaluated in the context of restoration of system potential riparian vegetation as required by the USEPA approved Deschutes River temperature TMDL.

Washington's water quality standards require that the TMDL be protective of water quality both in the river and in downstream waters. Therefore, potential instream nutrient targets will be evaluated for the most stringent standard, either based on the DO water quality standard applicable to the impaired segments of the Deschutes River or based on the conditions needed in the Deschutes River to protect water quality in Capitol Lake. Ex. 5 Deliberative Process (DP)

Ex. 5 Deliberative Process (DP)

Ex. 5 Deliberative Process (DP) Tetra Tech will utilize the calibrated QUAL2Kw model to simulate and evaluate natural conditions in the river. It is not anticipated that Tetra Tech will complete any GEMSS modeling. Should USEPA request that Tetra Tech complete any GEMSS modeling, the QAPP, TD, schedule and budget will be updated to reflect the addition of modeling tasks. Ex. 5 Deliberative Process (DP)

Ex. 5 Deliberative Process (DP)

To support the development of WLAs and LAs, existing loads for nutrients will be evaluated for point and nonpoint sources, where applicable. There are no individual wastewater facilities permitted to discharge to the Deschutes River (facilities in the lower portion of the watershed discharge to the Budd Inlet). Loads of oxygen demanding waste and nutrients from two fish hatcheries will be represented in the model . The first is a proposed fish hatchery to be located downstream of Pioneer Park and discharging to the Deschutes River. The second is a small existing hatchery which discharges into Tumwater Falls. The hatcheries will be incorporated as point sources in the TMDL requiring WLAs, or a future WLA, as appropriate. Although no monitoring data are available for these sources, estimated discharge data is expected to be provided by the Pioneer Park hatchery. The Tumwater Falls hatchery load will be evaluated using best estimates of loads from similar facilities.

Loads from nonpoint sources will also be tabulated as follows: 1) unit area loading rates of nitrogen and phosphorus by land use will be identified from literature relevant to western Washington, 2) land use areas draining to the impaired river will be tabulated, and 3) nutrient loads will be tabulated by multiplying the unit area loading rates with land use areas in the catchment. In addition, permitted MS4 loads will be tabulated separately (e.g., nutrient loads from impervious land within the MS4 boundary will be attributed to MS4s and not to nonpoint sources).. Separate existing loads will be computed for each permitted MS4 to support allocations. The QUAL2Kw model simulates a critical conditions period when stormwater (and MS4) contributions are zero. The QUAL2Kw model can still be used to approximate the needed reductions in long-term nutrient loading. Loading from the watershed, uptake by algae, and settling and decomposition of detrital matter are long-term processes that impact DO during the critical conditions period (e.g., through algal respiration and photosynthesis, sediment oxygen demand). Therefore, reductions in algae and/or sediment oxygen demand needed to achieve the

DO standard will be assessed with the QUAL2Kw model and applied proportionally to annual MS4 stormwater loads to support allocations.

IVB.1.2 Tributary TMDLs for Dissolved Oxygen, Temperature, and pH

TMDLs are being developed for nine tributary streams impaired for dissolved oxygen, temperature, and/or pH, and additional modeling is needed to support the revisions. Note that the technical direction for the initial phase of work will specify that a pilot model be developed for a select tributary (e.g., Ayer Creek, which is impaired for DO, pH, and temperature) and the technical direction will be revised if USEPA determines models should be developed for the remaining tributaries. The QAPP describes the approach that will be used for model development, calibration, and application, so it will not require revision based on this decision.

Riparian shade models will be developed for temperature impaired tributaries that currently lack Shade models to examine the potential thermal benefits of rejuvenating riparian vegetation. (Shade models have already been developed by Ecology for Black Lake Ditch and Percival Creek.) In addition, QUAL2Kw models will be developed to simulate water quality under critical conditions in each of the impaired tributary streams. The shade and QUAL2Kw models will be used to identify critical stressors and to derive stressor response curves; these curves will provide information regarding the relationships between stressors (e.g., riparian shade, nutrients) and the response variables of interest (DO, water temperature, and/or pH). A summary of the models to be developed is provided in [REF _Ref532303164 \h].

Point and nonpoint source loads will be quantified for the key stressor(s) identified for each tributary to support the WLA and LA process, where applicable (e.g., where nutrients are the key stressor for a DO or pH impairment). As part of this process, existing nutrient loads for permitted MS4s and nonpoint sources outside of MS4 boundaries will be tabulated using the approach described for the Deschutes River DO TMDL (see previous section). Pollutant loads for point sources (two fish hatcheries) will be characterized with input from USEPA because data are unavailable for these facilities. There are no permitted individual wastewater facilities that discharge to the Deschutes River. Modeling results will inform the selection of the constituent (or constituents) to use for daily loading capacities for each waterbody-pollutant pair. In addition to nutrients, sensitivity of DO to loads of carbonaceous biochemical oxygen demand (CBOD) will be assessed with the models, and CBOD will be considered as a potential constituent for which to derive daily loading capacities for the impaired waterbodies.

Percival Creek drains to Capitol Lake and the TMDL must be protective of the creek and downstream water quality in the lake. The potential need for applying a downstream standard more stringent than the standard applied directly to Percival Creek will be evaluated. Ex. 5 Deliberative Process (DP)

Ex. 5 Deliberative Process (DP)

Ex. 5 Deliberative Process (DP) Daily loading capacities will be calculated by Tetra Tech following guidance from USEPA regarding the regulatory requirement to be applied to Percival Creek (e.g., restore to natural conditions). Ex. 5 Deliberative Process (DP)

Ex. 5 Deliberative Process (DP)

Table [SEQ Table * ARABIC]. Modeling Approach to Support Development of Tributary TMDLs

Waterbody	Pollutants	Model Development
Huckleberry Creek	Temperature	- Develop Shade model to assess existing and potential riparian vegetation - Develop QUAL2Kw model to assess temperature response to thermal loads
Reichel Creek	Temperature, DO	- Develop Shade model to assess existing and potential riparian vegetation - Develop QUAL2Kw model to assess temperature and DO response to thermal loads and oxygen demanding pollutant loads (nutrients)
Tempo Lake Outlet	Temperature	- Develop Shade model to assess existing and potential riparian vegetation - Develop QUAL2Kw model to assess temperature response to thermal loads
Ayer Creek	Temperature, pH, and DO	- Develop Shade model to assess existing and potential riparian vegetation - Develop QUAL2Kw model to assess temperature, DO, and pH response to thermal loads and oxygen demanding pollutant loads (nutrients)
Unnamed Spring to Deschutes River	Temperature	- Develop Shade model to assess existing and potential riparian vegetation - Develop QUAL2Kw model to assess temperature response to thermal loads
Adams Creek	pH	- Develop QUAL2Kw model to assess pH stressor response
Black Lake Ditch	pH, DO	- Utilize existing Shade model to assess existing and potential riparian vegetation - Develop QUAL2Kw model to assess pH and DO stressor response
Lake Lawrence Creek	DO	- Develop QUAL2Kw model to assess DO stressor response
Percival Creek	DO	- Utilize existing Shade model to assess existing and potential riparian vegetation - Develop QUAL2Kw model to assess DO stressor response

IV.B.2 Deschutes River Fine Sediment Impairment

The portion of the Deschutes River between the confluence with Lake Lawrence Creek and the confluence with Reichel Creek is impaired for fine sediment. Loading capacities for the original TMDL submission were expressed in terms of percent fine sediment in gravels and were defined to achieve "Good" habitat quality for fishes and other aquatic species (<12% fines). The required reduction was established based on a field study by the Squaxin Island Tribe (Konovsky and Puhn, 2005) that measured percent fine sediment in gravels in the Deschutes River. USEPA agreed with the percent fines target and required reduction in loads but rejected the TMDL because a linkage between the assigned loading capacity and a targeted water quality condition was lacking.

Previous analyses (Raines, 2007) quantified fine sediment loads to the Deschutes River from bank erosion (hillslope and glacial terraces), landslides, and unpaved roads. The estimated rates and relative contributions of these fine sediment sources were assessed at the point of inflow to Capitol Lake. The section of the Deschutes River listed as impaired for fine sediment and for which a TMDL is being developed is located further upstream, spanning the section of the river from Lake Lawrence Creek to Reichel Creek. Sediment loading rates from forest roads and bank erosion estimated by Raines (2007) will be retained, but recalculated for the area upstream of the impaired segments of the Deschutes River (no additional modeling will be completed for these sources).

Approximately 22% - 32% of the sediment load to Capitol Lake was unaccounted for in the previous mass balance analysis, as discussed in a report prepared for the Squaxin Island Tribe (Raines, 2007):

"The bank erosion, road sediment, and landslide analyses and sediment budget results (Tables 8 and 9) suggest the following: 1. The partial list of sediment sources quantified in this report accounts for the majority, 68 to 78 percent, of estimated sediment exiting the Deschutes River as defined by dredging and bathymetric records of Capitol Lake during the 31 years from 1972 to 2003. 2…"

More information is needed regarding other sources of sediment and the tasks outlined below will help to address gaps in the original source assessment.

As part of the revision, average annual soil loss from sheet and rill erosion in the drainage area will be modeled with the Revised Universal Soil Loss Equation (RUSLE) method (Renard, 1997). The RUSLE method estimates sheet and rill erosion caused by rainfall and its associated runoff through five multiplicative factors:

$$A = R * K * LS * C * P$$

Where A is the average annual soil loss from sheet and rill erosion caused by rainfall and its associated overland flow (short tons/acre/year). The input factors are summarized in [REF _Ref532303333 \h].

Table [SEQ Table * ARABIC]. RUSLE Factors

RUSLE Variable	RUSLE Factor
R	Rainfall-Runoff Erosivity Factor
K	Soil Erodibility Factor
LS	Slope Length and Steepness Factor
C	Cover-Management Factor
P	Support Practice Factor

The RUSLE approach will be implemented spatially (grid-based) and parameter inputs will build on equations and recommendations found in the RUSLE's user guide to estimate upland soil loss. RUSLE does not directly estimate downstream delivery of this sediment, much of which may be trapped near the source. It is common practice to apply a sediment delivery ratio (SDR) to RUSLE soil loss to estimate sediment yield to the river. The SDR will be estimated as described below.

Borselli et al. (2008) developed advanced geographical information system (GIS) techniques for determining sediment and flow connectivity on landscapes and the method has been extended to provide parametric landscape-based estimates of sediment delivery ratios (SDRs) that can be used with grid-based applications of RUSLE (e.g., Vigiak et al., 2012). This provides an effective means of converting the RUSLE analysis to an estimate of net (delivered) sediment yield from upland sources.

The RUSLE-SDR method will be implemented to support the fine sediment TMDL for the Deschutes River. Average sediment yields from upland erosion will be tabulated by land use to support allocation efforts.

There are no permitted MS4s, individual wastewater facilities, or relevant general permits (e.g., sand and gravel facilities, construction stormwater) upstream of the sediment impaired segment. Therefore, no point source loads will be quantified.

The modeling results will be combined with past studies of sediment sources to calculate the total existing sediment load from nonpoint sources upstream of the impairment. USEPA's *Protocol for Developing Sediment TMDLs* provides several potential options for linking water quality targets to sources of sediment (USEPA, 1999). As discussed in Section IV.B, mechanistic (e.g., SWAT) or empirical linkage models may be used if resources allow and data availability is adequate, but these approaches will not be used for the Deschutes River fine sediment TMDL due to time constraints and data limitations. The linkage between sediment sources and fine sediment in gravels will be determined through a direct arithmetic linkage. The needed percent reductions in fine sediment in gravels can be calculated from field survey data and the healthy habitat levels established in the Timber Fish and Wildlife Watershed Analysis Manual (Washington Forest Practices Board, 1997; Roberts et al., 2012). Habitat quality ratings of poor, fair, and good are attributed to percent fine sediments in gravels of >17%, 12 to 17%, and <12%, respectively. Field survey data from 2004 indicates the percent fine sediment in gravel for the impaired sediment was 17.1% (Segment 22 in Table 33 of Roberts et al., 2012). A target for percent fine sediment in gravels will be established for the TMDL with guidance from USEPA. The target will be paired with the existing fine sediment in gravels percentage (17.1%) to calculate the needed reduction. For example, if a target of 12% is selected then the required reduction will be 30%. The required percent reduction in fine sediment will be applied proportionally to the existing total sediment load to the impairment (from bank erosion, landslides, unpaved roads, and sheet and rill erosion) to establish the daily loading capacity (i.e., loading capacity = total existing sediment load * (1 – required percent reduction expressed as a fraction)). In Ecology's *Technical Report* a percent fine sediment in gravels target of 12% was established (Roberts et al., 2012; Table 33). It is anticipated that this target will be maintained, however, if preferred by USEPA a lower target could be applied as an explicit MOS.

An additional analysis will be completed to ensure that the turbidity criterion is also achieved for the fine sediment impaired reach. The total sediment load from the mass balance assessment will be paired with flow records at Deschutes River near Rainier, Washington (USGS 12079000) to approximate the resulting total suspended sediment concentration. A previously developed relationship between total suspended sediment and turbidity for streams in the Puget Lowlands will be applied to estimate the resulting turbidity (Packman et al., 1999), which will be compared to the applicable turbidity criterion that depends on the background turbidity condition. When background turbidity is 50 nephelometric turbidity units (NTU) or less, the turbidity shall not exceed 5 NTU over background. When background turbidity is more than 50 NTU there cannot be more than a 10% increase in NTU. A recently completed N-STEPS (Nutrient Scientific Technical Exchange Partnership and Support) assessment for Washington estimated the mean turbidity for the least disturbed, reference stream monitoring sites in ecoregion 2 (Puget Lowlands) as equal to 0.933 NTU (median 1.2 NTU; Tetra Tech, 2018). The loading capacity developed for fine sediment will be reduced if the estimated turbidity exceeds the criterion.

IV.C LOAD-DURATION CURVES FOR BACTERIA

Analyzing pollutant levels in conjunction with water quality standards and flow is useful for assessing critical conditions, and existing and required loads. The Load-Duration Curve Method (Stiles, 2001, 2002; Cleland, 2002, 2003) will be used to assess the fecal coliform impairments. This method plots flow and observed data to examine the flow conditions under which impairment occurs and water quality deviates from the standard. A flow-duration curve analysis will be performed to identify the flow regimes during which excursions of the most stringent bacteria criterion occur. This method determines the relative ranking of a given flow based on the percent of time that historic flows exceed that value. Long-term gaging records are not available for the bacteria impaired creeks, thus historic flow regimes will be estimated by scaling daily flows observed at the USGS Deschutes River at Tumwater gage based on relative drainage area. Once relative rankings are calculated for flow, existing bacteria loads will be computed. This type of analysis can help define the flow regime during which excursions occur, which can help identify the key sources contributing to the impairment. The Load-Duration Curve approach will also be used to determine assimilative capacity for each bacteria-impaired creek, evaluated for both the target geometric mean and highest allowable 10th percentile of samples. A Margin of Safety (MOS) will be incorporated into each of the bacteria TMDLs as determined by USEPA.

Protection of downstream water quality was not explicitly assessed in the original bacteria TMDLs. In addition to meeting targets applicable to the waterbody based on its designated use, conditions in the waters must not degrade downstream water quality. Since five bacteria-impaired tributaries drain directly to Budd Inlet, revisions to the technical analyses will seek to evaluate downstream impacts of bacteria in these creeks.

Two of the tributaries, Moxlie Creek and Schneider Creek, drain to Inner Budd Inlet, which is directly downstream of Capitol Lake. The location of this part of Budd Inlet is described in Washington's Water Quality Standards as "Budd Inlet south of latitude 47°04'N (south of Priest Point Park)." The water quality standard for this portion of Budd Inlet is secondary contact recreation. This standard is established in terms of enterococci; thus, a translation, through application of a fecal coliform to enterococci ratio or regression relationship, will be applied to determine the most stringent standard for Moxlie Creek and Schneider Creek. Paired enterococci and fecal coliform samples (i.e., collected at the same location at the time) from waterbodies in the region will be used to derive the relationship between the bacteria indicators.

The remaining three tributaries (Adams Creek, Ellis Creek, and Mission Creek) drain to Budd Inlet/South Puget Sound, which is directly downstream of Inner Budd Inlet. The location of this part of Budd Inlet is described in Washington's Water Quality Standards as "South Puget Sound west of longitude 122°52'30"W (Brisco Point) and longitude 122°51'W (northern tip of Hartstene Island, except as otherwise noted)." This portion of Budd Inlet/South Puget Sound has a stringent fecal coliform criterion to safeguard shellfish habitat.

Loading capacities for the creeks will be developed based on the most stringent target, either the bacteria standard directly applicable to the creek or the bacteria standard applicable to the receiving water (Inner Budd Inlet or Budd Inlet/South Puget Sound), to ensure protection of water quality in the creeks and waters directly downstream of the five tributaries.

Stormwater discharges via designated Municipal Separate Storm Sewer Systems (MS4s) are subject to NPDES permits. Bacteria loads from MS4s will need to be separately accounted for from other stormwater sources because they are subject to WLAs rather than nonpoint source LAs in the TMDL (USEPA, 2001b). To support this effort, existing fecal coliform loads attributed to permitted MS4s will be estimated. It is hypothesized that the bacteria load during moderate to high-flow periods (i.e., storm-event periods) is dominated by contributions from stormwater, including stormwater discharged from permitted MS4s. However, the bacteria load during low flow periods (i.e., non-storm event periods) is dominated by loads from subsurface nonpoint sources (e.g., onsite wastewater disposal systems) and point sources, if applicable. There are no individual wastewater facilities permitted to discharge to the bacteria impaired creeks. The load during moderate to high flow periods will be apportioned between MS4 and non-MS4 sources. This will be accomplished by tabulating the proportion of the creek's drainage area under MS4 regulations (e.g., impervious land within the MS4 boundary) and apportioning the total load to MS4s and non-MS4 areas. Separate loads will be computed for each permitted MS4 (based on regulated area) to support allocations.

USEPA may also request support on bacteria allocation approaches and calculations (if so, this will be specified in the Technical Direction). For example, a brief memorandum that proposes an approach to establish potential WLAs for individual stormwater permittees (i.e., MS4s) and LAs for nonpoint sources of bacteria could be prepared and allocations calculated. Since the Load-Duration Curve Method is not a model this potential discussion and effort may be used without modifications to the QAPP, but will need to be included in the TD.

IV.D SOFTWARE DEVELOPMENT QUALITY ASSESSMENT

It is not anticipated that software code modifications or development of new code will be needed to complete the water quality modeling for the Deschutes TMDLs.

SECTION V: MODEL DEVELOPMENT

V.A MODEL BOUNDARIES

The Deschutes River originates from the west central Cascade Mountain range, meanders northwestward towards Olympia, Washington, and flows to Capitol Lake, which discharges to Budd Inlet and eventually into the Southern Puget Sound ([REF _Ref532458181 \h]). The TMDL analyses will address the respective drainage areas of the impaired segments in the Deschutes River watershed. It will also address several tributaries that drain directly to Budd Inlet adjacent to the Deschutes River watershed. Boundary conditions to be represented in the riverine QUAL2Kw models include upstream boundaries, tributary inflows, groundwater inflows, direct point source discharges, diffusive nonpoint sources, fluxes at the air-water and water-sediment interfaces, and meteorological conditions.

V.B SPATIAL AND TEMPORAL RESOLUTION

The spatial and temporal resolutions of the analyses will differ for the impairments as appropriate but will aim to represent current conditions in the waterbodies. Load-Duration Curves will be developed for the bacteria impaired creeks, and bacteria data collected along the length of the impaired segment will be applied for the analysis. Most of the available fecal coliform samples were collected in the mid-2000s. Continuous flow records are also not available for the bacteria impaired creeks; therefore, flow records from the USGS gage located on the Deschutes River at Tumwater will be scaled based on the full delineated drainage area of the bacteria impaired segment. Daily loading capacities for different flow profiles will be provided as the final temporal resolution for the bacteria TMDLs.

The full spatial resolution of each Shade and QUAL2Kw model for the temperature, pH, and DO impairments will, at a minimum, span the length of the polluted segment (i.e., listing ID(s)). For the impaired tributaries, each QUAL2Kw model is anticipated to span the full length of the flowing stream and will be simulated as segments in series. Where appropriate, informative, and where data supports it, segments upstream and downstream of the impairment will also be explicitly modeled; for example, the existing QUAL2Kw mainstem model simulates conditions in the Deschutes River from near the Deschutes Falls to the mouth of the river at Capitol Lake. Tributary inflows, direct point source discharges, and diffusive nonpoint sources will be represented as boundary conditions in the QUAL2Kw models. Each Shade model built for a temperature impaired segment will include the riparian zone spanning the full length of the impaired segment. Outputs from the Shade model will be used as inputs for the waterbody's QUAL2Kw model, which will be used to predict diurnal instream response. QUAL2Kw simulates diel water quality kinetics under steady-state flow in one-dimensional reaches with hourly inputs for headwater boundary conditions, weather variables, and shade. The QUAL2Kw model will be used to quantify the loads of key stressors needed to achieve the water quality criterion (e.g., riparian shade for a water temperature impairment). This information will be used to develop daily loading capacities for key stressors.

RUSLE modeling for the Deschutes River fine sediment TMDL will estimate annual average sediment loads from sheet and rill erosion delivered to the impaired segment. A spatial modeling approach, implemented through ArcGIS, will be used. As described in Section V.D, the data sources that will be used to develop the input grids vary in resolution. All grids will be scaled to 10 m for modeling to maintain the detail of the finest resolution datasets. The results will represent annual average daily loads.

V.C SOURCE CHARACTERISTICS

A critical component of water quality modeling and developing a useful TMDL is the assessment of potential sources. Both point and nonpoint sources can contribute pollution to the waterbodies. Land use data provides information about the potential types of nonpoint pollutant sources that should be reviewed ([REF _Ref532463449 \h]).

Potential sources of bacteria include wildlife, pet waste, malfunctioning onsite wastewater systems, agricultural management (e.g., manure fertilizer), animal operation facilities, and wastewater treatment plant effluent. The land contributing flow to several of the bacteria impaired creeks that drain directly to Budd Inlet is primarily developed ([REF _Ref532462493 \h]). Therefore, it is likely that the most important bacteria sources are wildlife, pet waste, and onsite wastewater disposal (septic) systems. There are no wastewater treatment plants that are permitted to discharge to the relatively small creeks. However, land regulated under MS4 permits drains to some of the bacteria impaired creeks and loads from MS4s will need to be accounted for separately ([REF _Ref532462498 \h]).

Natural heat exchanges at the air-water (e.g., solar radiation, convective heat exchange) and water-sediment interfaces will be represented in the QUAL2Kw models. Potential human sources that contribute to temperature impairments include destruction to shade-providing riparian vegetation, heat loads from point source effluent, and water diversions that reduce baseflow. The impacts of current and potential riparian shade and other activities that impact stream temperatures will be examined through joint applications of the Shade and QUAL2Kw models.

There are several sources that must be considered as potentially contributing to the DO deficits in the lower Deschutes River and other DO impaired segments. Human activities that can contribute to the DO deficit include degradation of shade-providing riparian vegetation that cools water temperatures and limits algal growth, nonpoint source oxygen-demanding pollutant loads (e.g., fixed carbon in detrital biomass, point source oxygen-demanding pollutant loads, nutrient loads that promote excess plant and algal growth, low DO associated with waste discharges to ground water, and altered streamflow regimes caused by development or land management practices. These sources will be represented in the QUAL2Kw models as point or diffusive inflows or outflows or serve as input parameters (e.g., percent shade).

Variations in pH beyond the target range of 6.5 to 8.5 may be attributed to multiple sources, including rainwater pH, point source effluent, or indirectly from excess nutrient loads that stimulate biological activity. During daylight hours, algae photosynthesize, producing oxygen (O_2) while removing carbon dioxide (CO_2) and bicarbonate ions (HCO_3-), and increasing instream hydroxide (OH-) and pH. At night algae respire, producing carbon dioxide (CO_2) and decreasing instream hydroxide (OH-) and pH. These potential sources will be assessed for the pH impairments using the QUAL2Kw models.

Key sources of fine sediment include landslides, erosion of unpaved roads, sheet and rill erosion of pervious land surfaces (primarily forest and agricultural lands upstream of the impaired segment), and scour and degradation of channel banks and beds.

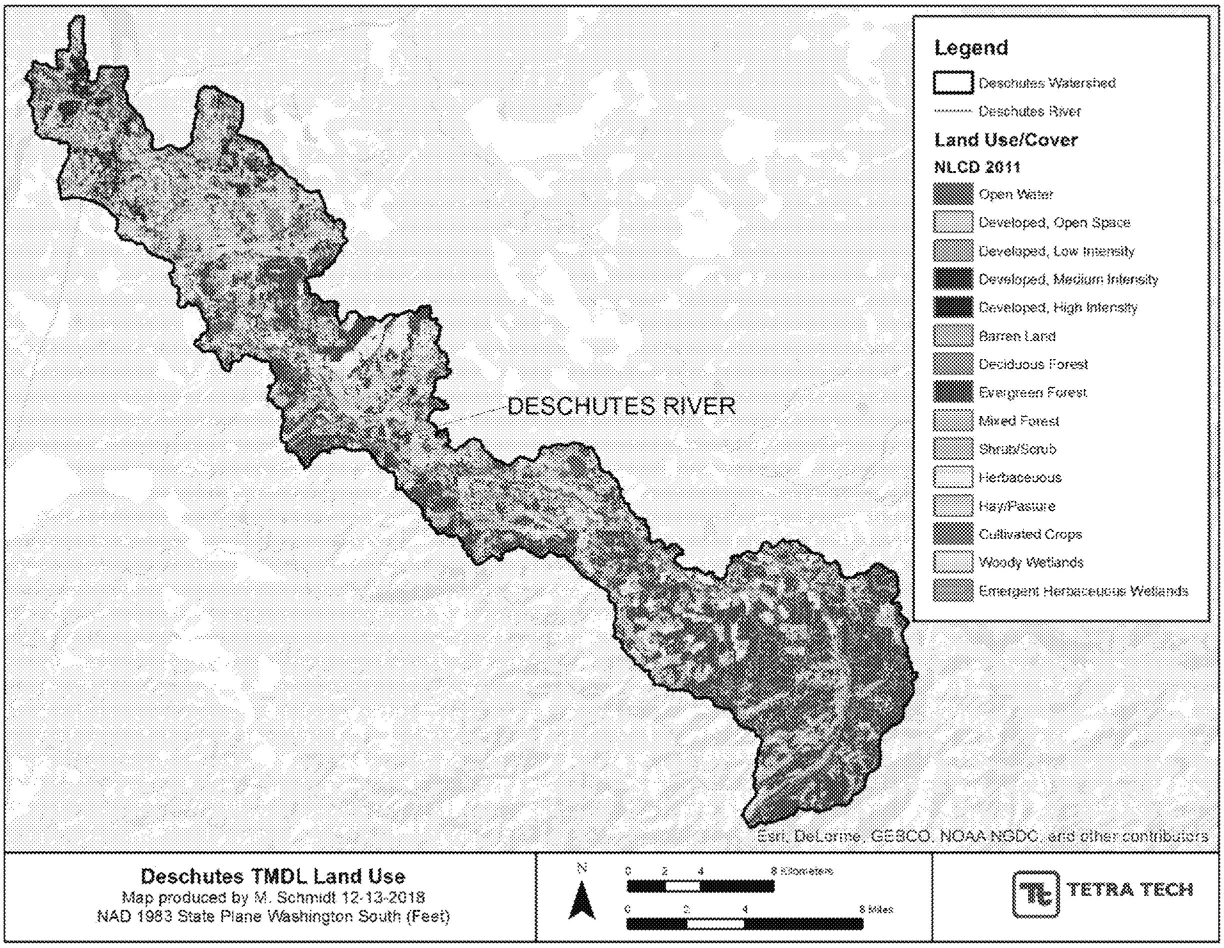


Figure [SEQ Figure * ARABIC]. NLCD 2011 Land Use/Cover in the Deschutes River Watershed

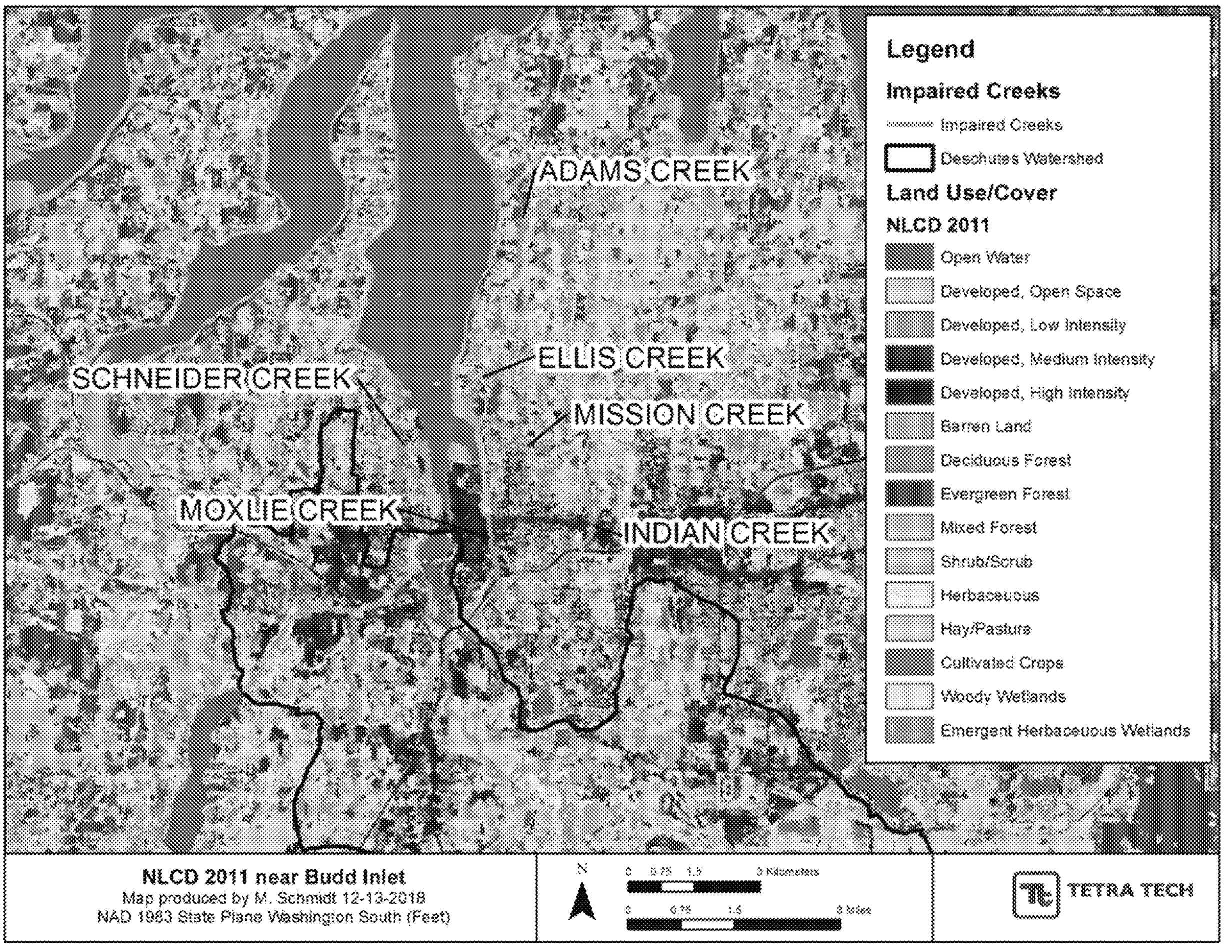


Figure [SEQ Figure * ARABIC]. NLCD 2011 Land Use/Cover near Budd Inlet

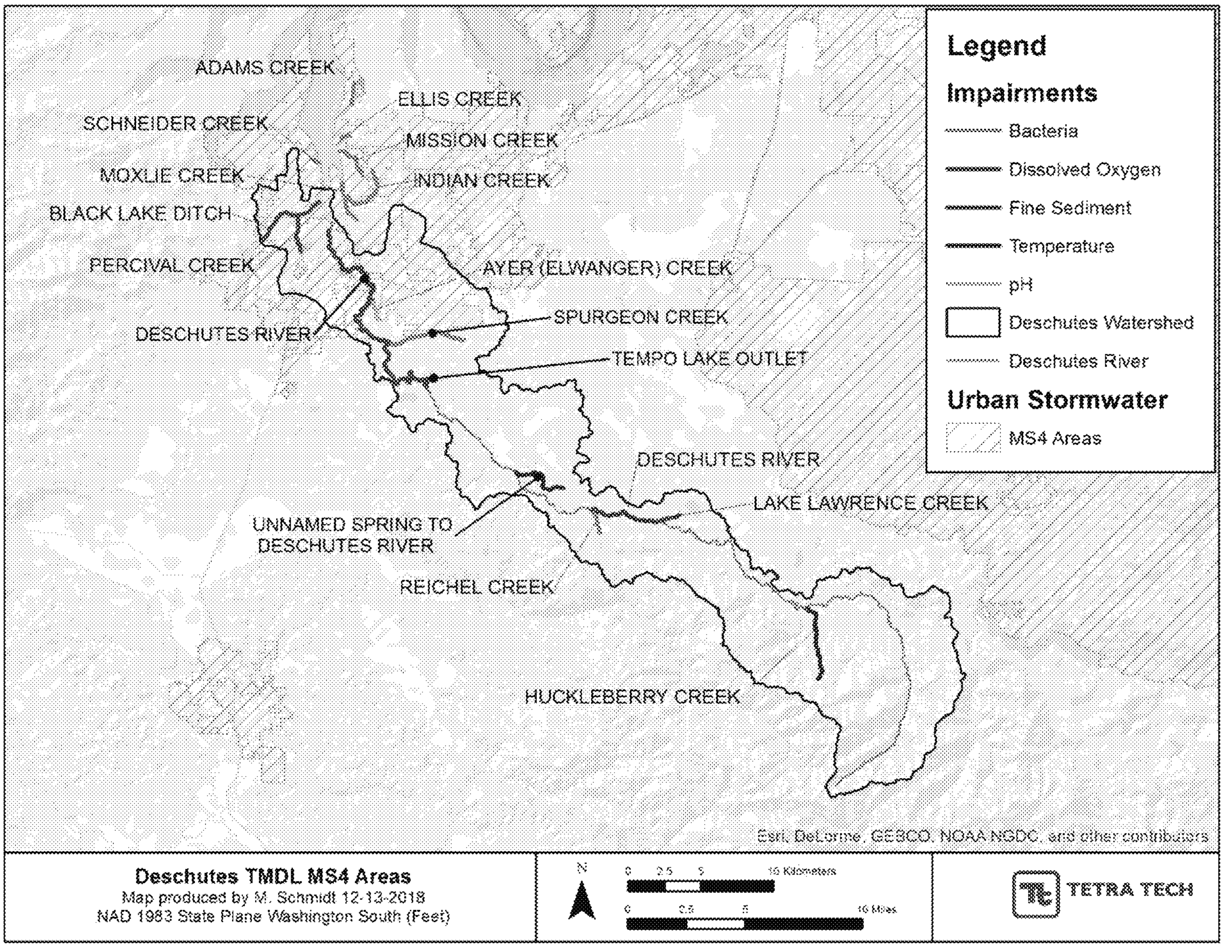


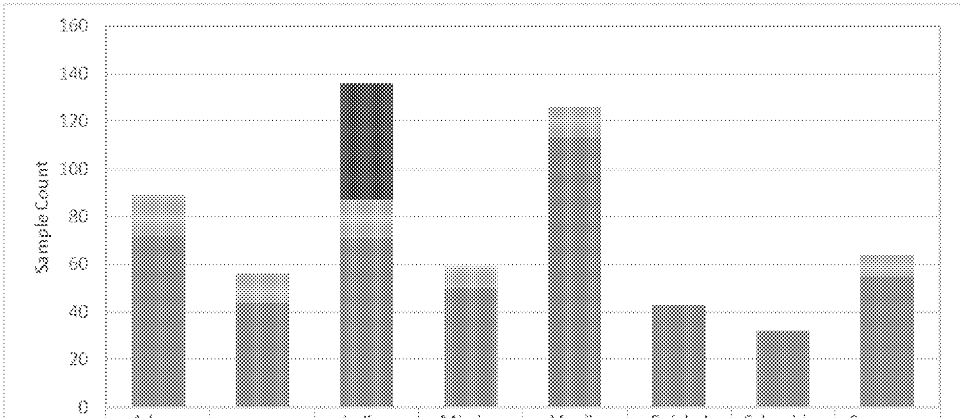
Figure [SEQ Figure * ARABIC]. Municipal Separate Storm Sewer Systems (MS4s)

V.D DATA AVAILABILITY AND QUALITY

The work to be conducted under this QAPP will not include the collection of new direct measurements of environmental conditions. Nondirect measurements (also referred to as secondary data) are data previously collected under an effort outside this contract that are used for model development and calibration. Secondary data for application in the Deschutes TMDLs project will be assembled from other sources. The sections below provide details regarding how such secondary data will be identified, acquired, and used for this project.

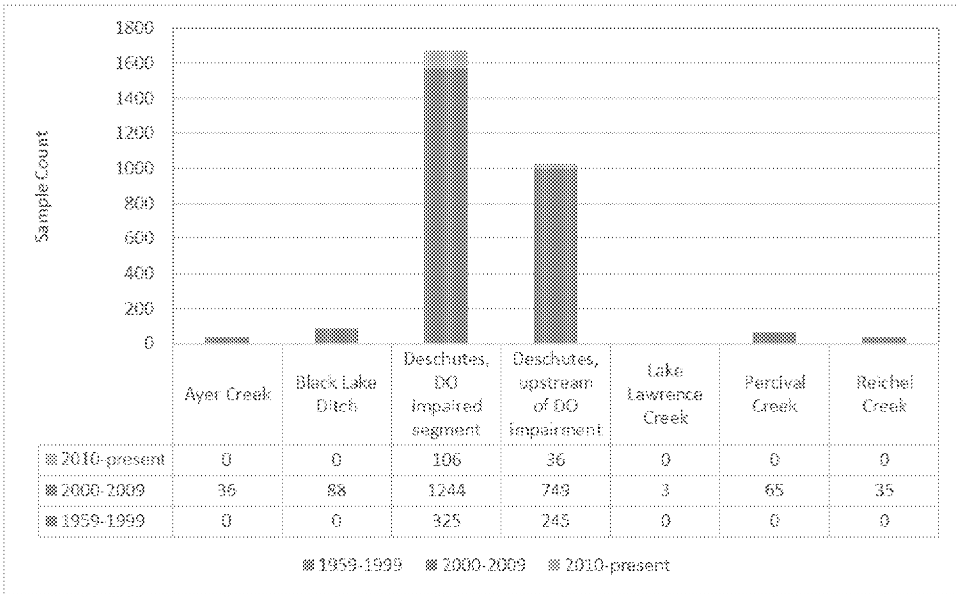
Water quality monitoring is an important data source for model development, calibration, and evaluation and other TMDL analyses. A preliminary compilation and review of available data was completed to support the development of the technical approach and this QAPP (Technical Direction for Phase I under EP-C-17-046 Task 0001) in accordance with Tetra Tech's (2016) *Quality Management Plan for Technical Support for Assessment and Watershed Protection*. Available data will be used to support the modeling and assessment of current conditions within the impaired waterbodies. Environmental monitoring data collected by Ecology, partner agencies, and other researchers is made publicly available through Washington's Environmental Information Management System (EIM). Water quality data for impaired waterbodies in the

Deschutes River watershed and those draining directly to Budd Inlet were extracted from the online EIM database. Fecal coliform, DO, pH, temperature, and nutrient data are summarized by pollutant and collection period/year in [REF _Ref853979 \h] through [REF _Ref878304 \h]. Monitoring site maps are provided in [REF _Ref854330 \h] through [REF _Ref854335 \h]. Data from continuous measurements available through EIM are included in the totals (e.g., 15-minute interval DO data collected in the Deschutes River in August 2004). Monitoring records for recent years (collected between 2010-present) are limited. In addition to the data shown in the plots, two chlorophyll *a* samples were collected in 2015 for the DO impaired segment of the Deschutes River. Most of the data available for the impaired tributaries comes from assessments conducted between 2003-2004. It is anticipated that all available monitoring data will inform modeling and assessment efforts, but the use of older data (e.g., DO data for the Deschutes River collected in the 1960s – 1980s) will be reviewed and evaluated to determine its applicability to current conditions.



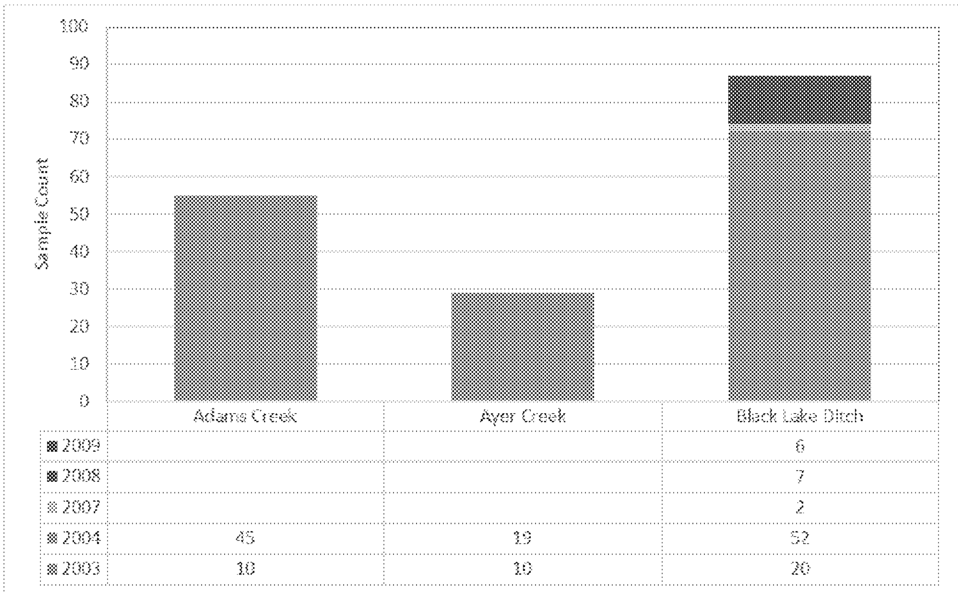
	Adams Creek	Ellis Creek	Indian Creek	Mission Creek	Moxlie Creek	Reichel Creek	Schneider Creek	Spurgeon Creek
2008			49					
2005	17	12	16	9	13			9
2004	61	34	58	38	85	29	21	45
2003	11	10	13	12	28	14	11	10

Figure [SEQ Figure * ARABIC]. EIM Fecal Coliform Grab Sample Summary for Bacteria Impaired Waterbodies



	Ayer Creek	Black Lake Ditch	Deschutes, DO impaired segment	Deschutes, upstream of DO impairment	Lake Lawrence Creek	Percival Creek	Reichel Creek
2010-present	0	0	106	36	0	0	0
2000-2009	36	88	1244	749	3	65	35
1959-1999	0	0	325	245	0	0	0

Figure [SEQ Figure * ARABIC]. EIM Dissolved Oxygen Grab Sample Summary for Oxygen Impaired Waterbodies



	Adams Creek	Ayer Creek	Black Lake Ditch
2009			6
2008			7
2007			2
2004	45	19	52
2003	10	10	20

Figure [SEQ Figure * ARABIC]. EIM pH Grab Sample Summary for pH Impaired Waterbodies

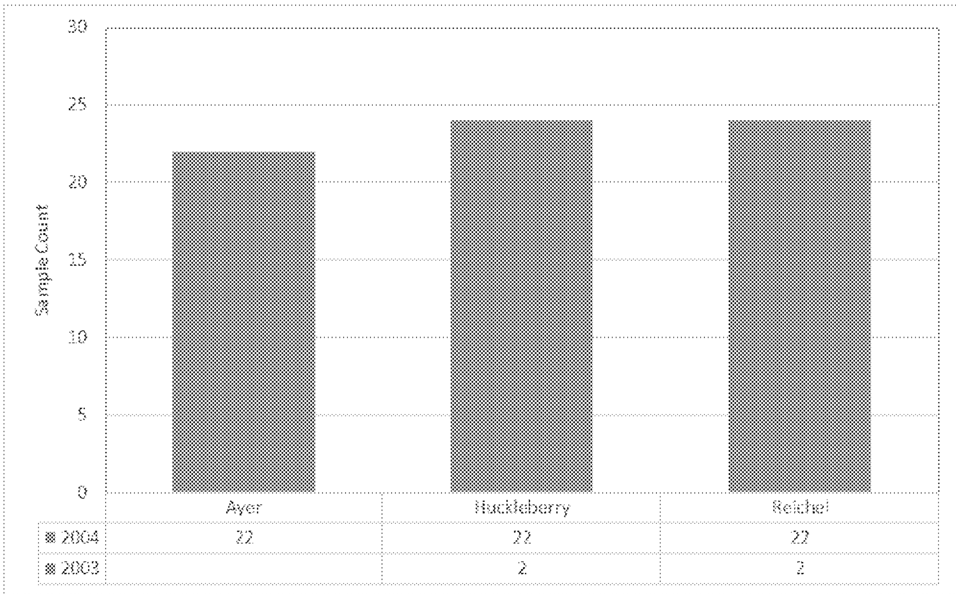
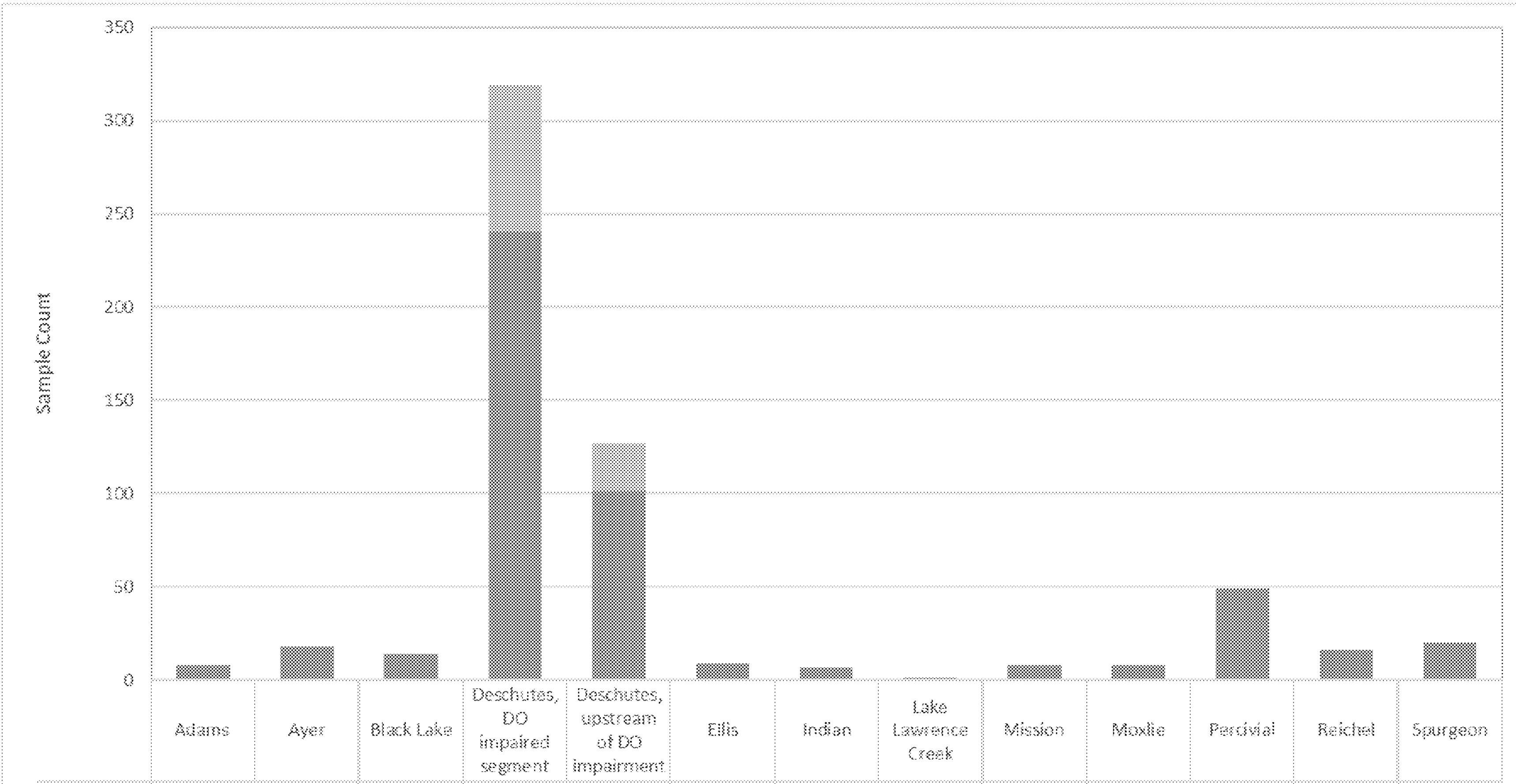
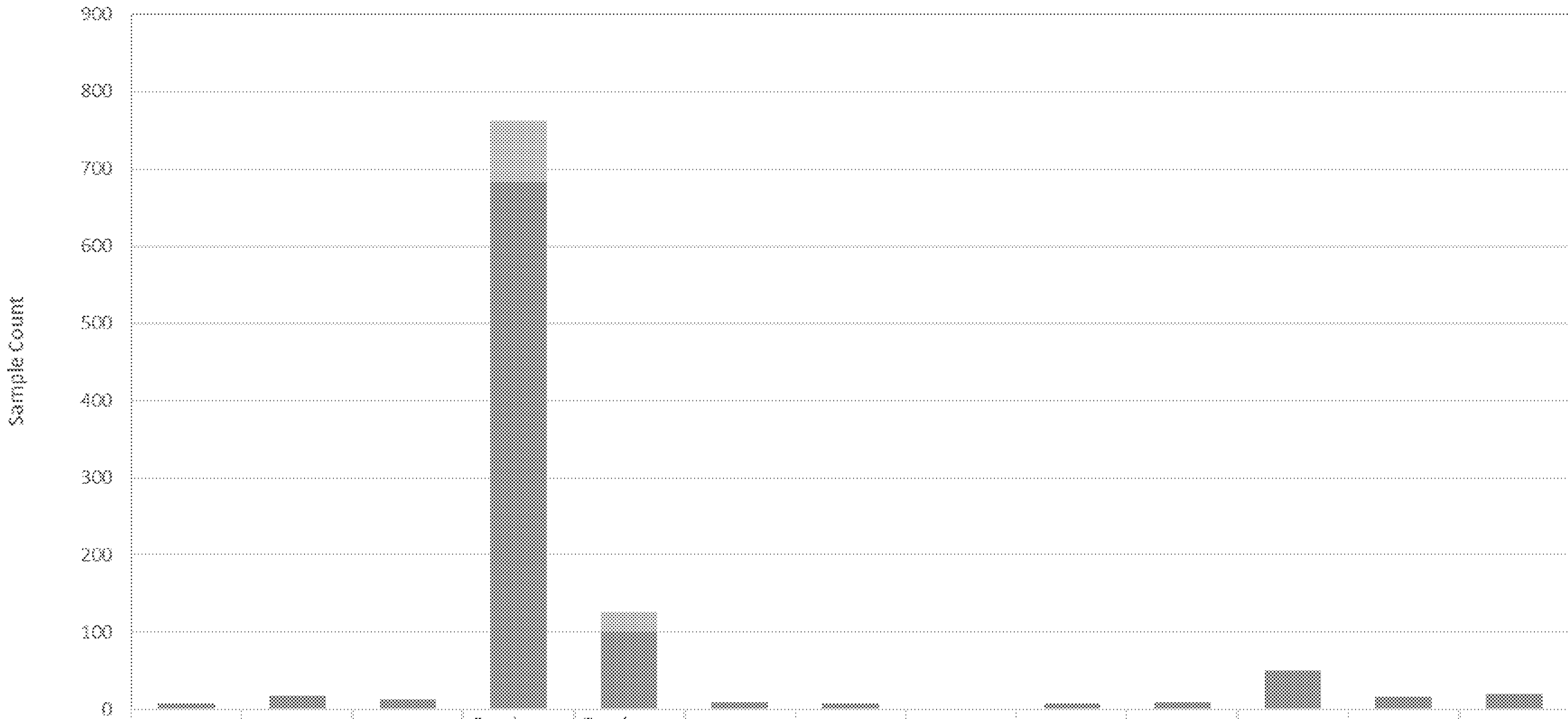


Figure [SEQ Figure * ARABIC]. EIM Water Temperature Grab Sample Summary for Temperature Impaired Waterbodies



	Adams	Ayer	Black Lake	Deschutes, DO impaired segment	Deschutes, upstream of DO impairment	Ellis	Indian	Lake Lawrence Creek	Mission	Moxlie	Percivial	Reichel	Spurgeon
2012-2018	0	0	0	78	26	0	0	0	0	0	0	0	0
2006-2011	0	0	0	72	0	4	0	0	4	4	0	0	0
2000-2005	8	18	14	169	101	5	7	1	4	4	49	16	20

Figure [SEQ Figure * ARABIC]. EIM Ammonia Grab Sample Summary for Impaired Waterbodies



	Adams	Ayer	Black Lake	Deschutes, DO impaired segment	Deschutes, upstream of DO impairment	Ellis	Indian	Lake Lawrence Creek	Mission	Moxlie	Percivial	Reichel	Spurgeon
2012-2018	0	0	0	79	26	0	0	0	0	0	0	0	0
2006-2011	0	0	0	515	0	4	0	0	4	4	0	0	0
2000-2005	8	18	14	169	101	5	7	1	4	5	50	16	20

Figure [SEQ Figure * ARABIC]. EIM Nitrite-Nitrate Grab Sample Summary for Impaired Waterbodies

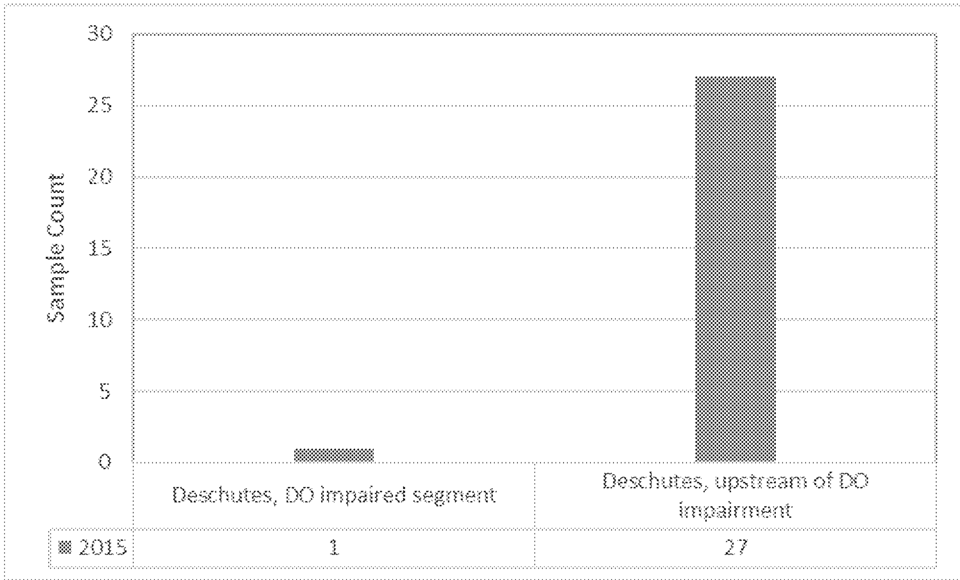
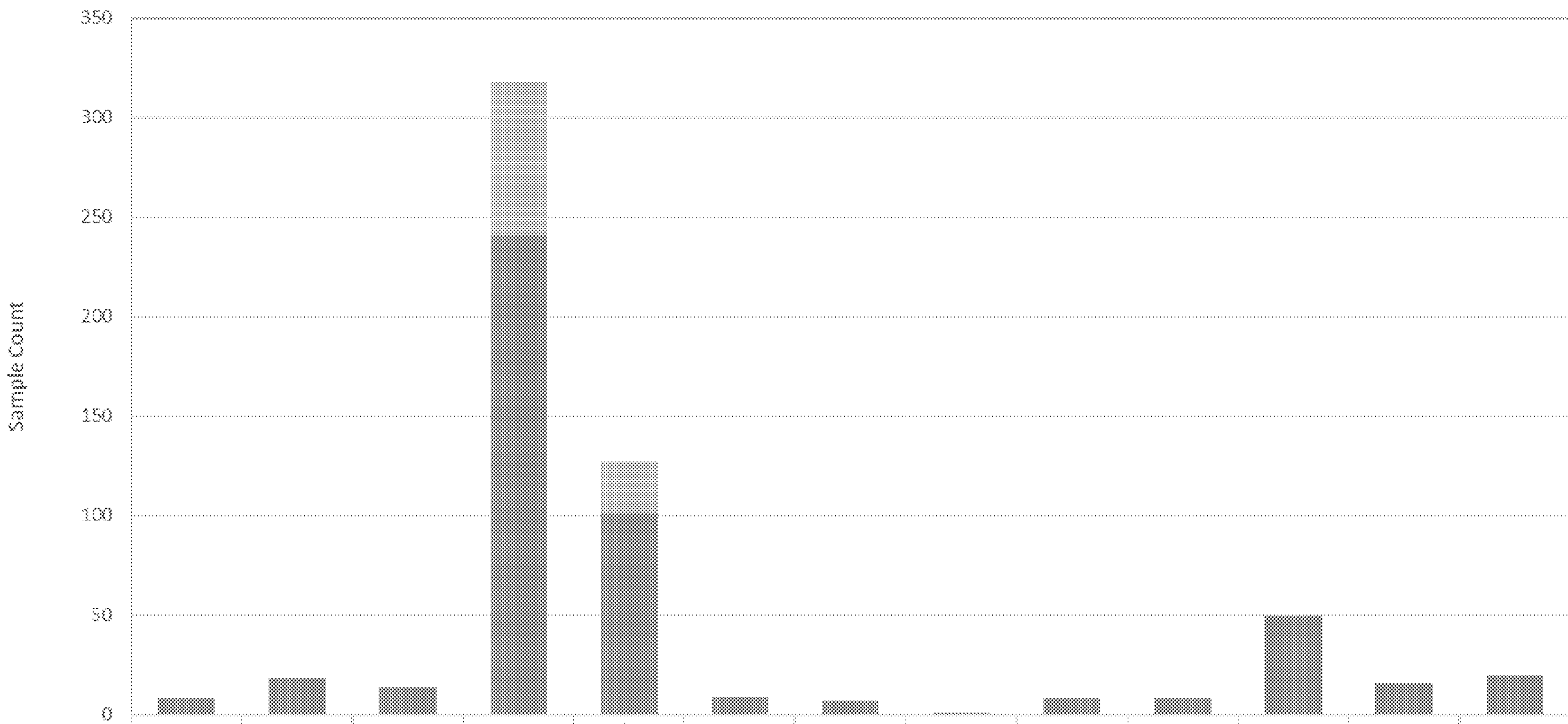
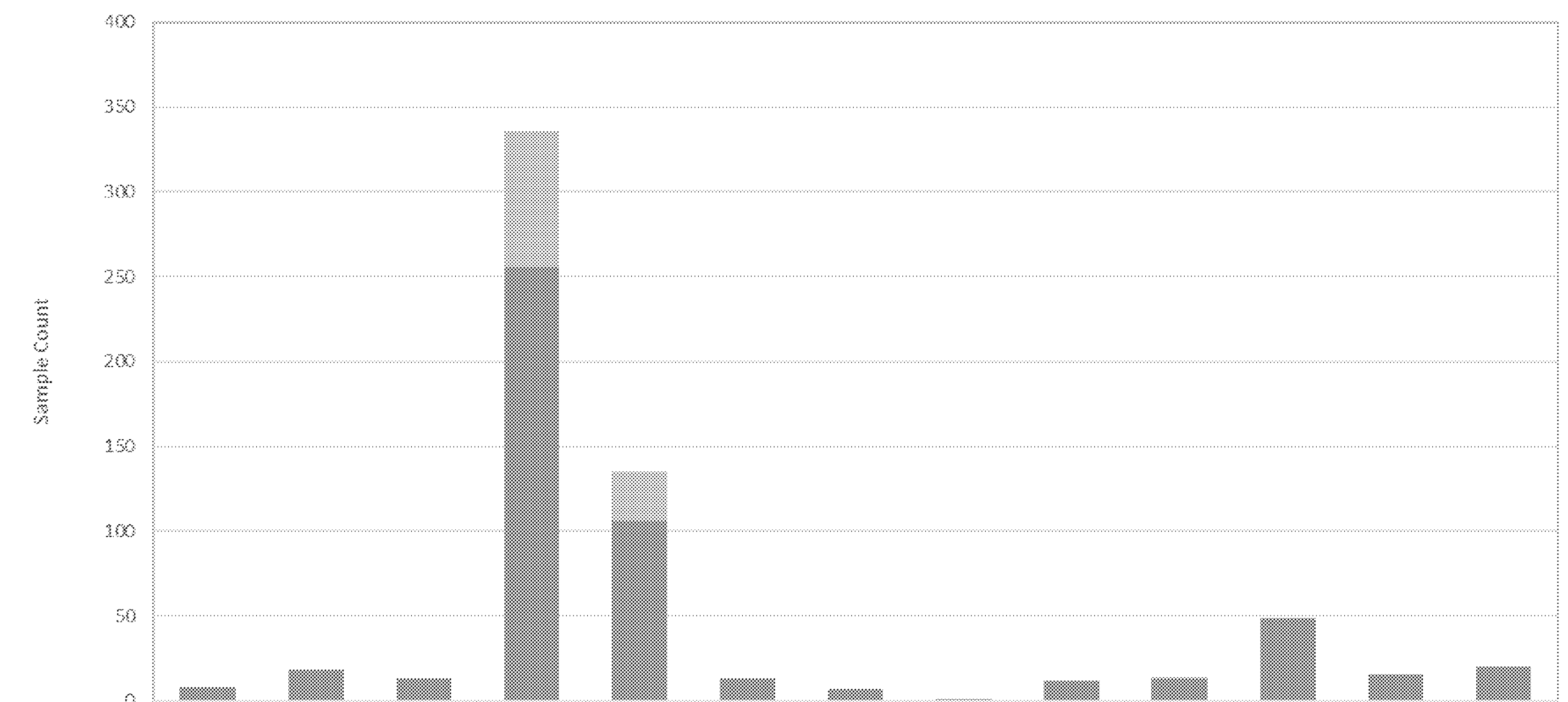


Figure [SEQ Figure * ARABIC]. EIM Total Nitrogen Grab Sample Summary for Impaired Waterbodies



	Adams	Ayer	Black Lake	Deschutes, DO impaired segment	Deschutes, upstream of DO impairment	Ellis	Indian	Lake Lawrence Creek	Mission	Moxlie	Percivial	Reichel	Spurgeon
2012-2018	0	0	0	77	26	0	0	0	0	0	0	0	0
2006-2011	0	0	0	72	0	4	0	0	4	4	0	0	0
2000-2005	8	18	14	169	101	5	7	1	4	4	50	16	20

Figure [SEQ Figure * ARABIC]. EIM Orthophosphate Grab Sample Summary for Impaired Waterbodies



	Adams	Ayer	Black Lake	Deschutes, DO impaired segment	Deschutes, upstream of DO impairment	Ellis	Indian	Lake Lawrence Creek	Mission	Moxlie	Percivial	Reichel	Spurgeon
2012-2018	0	0	0	80	29	0	0	0	0	1	0	0	0
2006-2011	0	0	0	88	4	8	0	0	8	8	0	0	0
2000-2005	8	18	13	168	102	5	7	1	4	5	49	16	20

Figure [SEQ Figure * ARABIC]. EIM Total Phosphorus Grab Sample Summary for Impaired Waterbodies

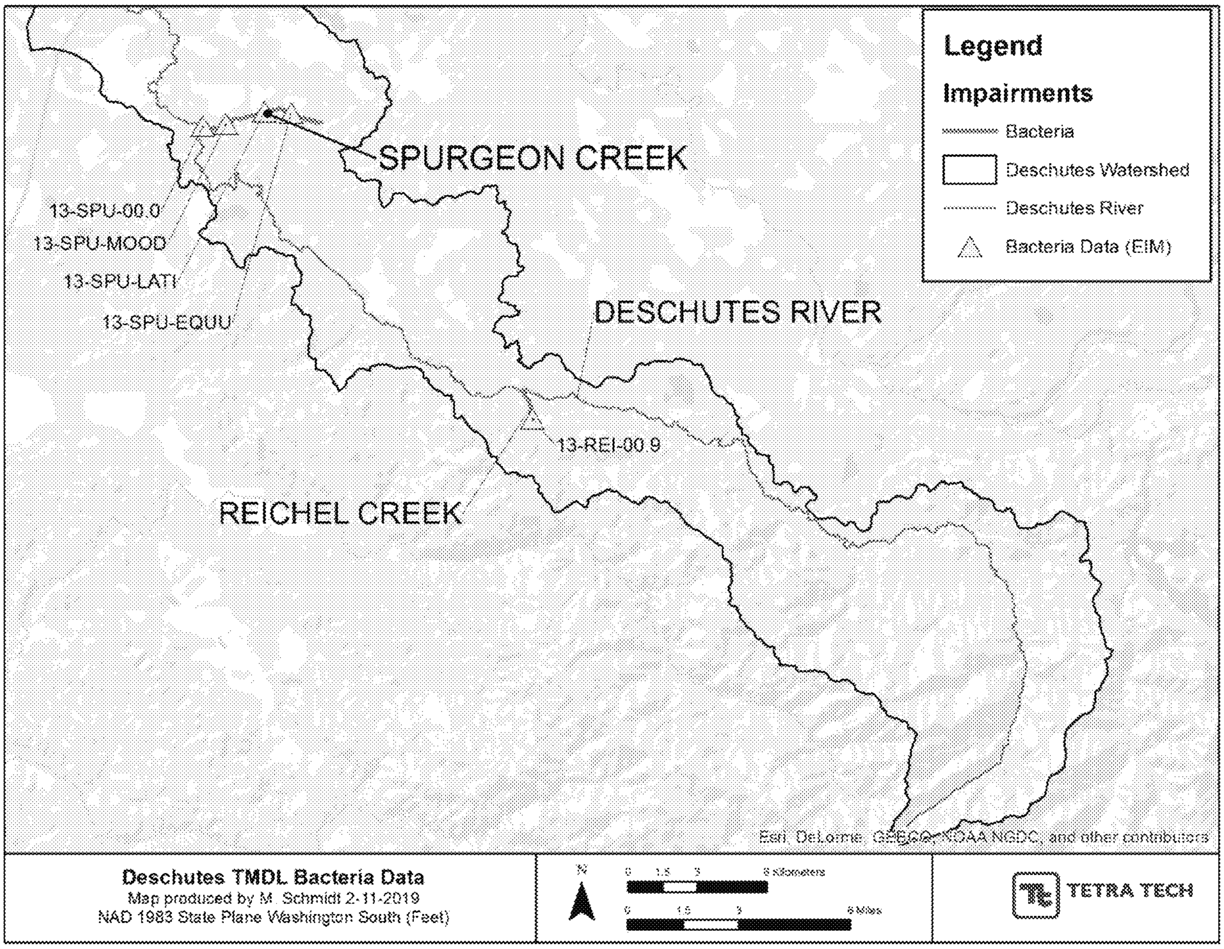


Figure [SEQ Figure * ARABIC]. EIM Bacteria Sampling Locations for Bacteria Impairments (Upper Deschutes)

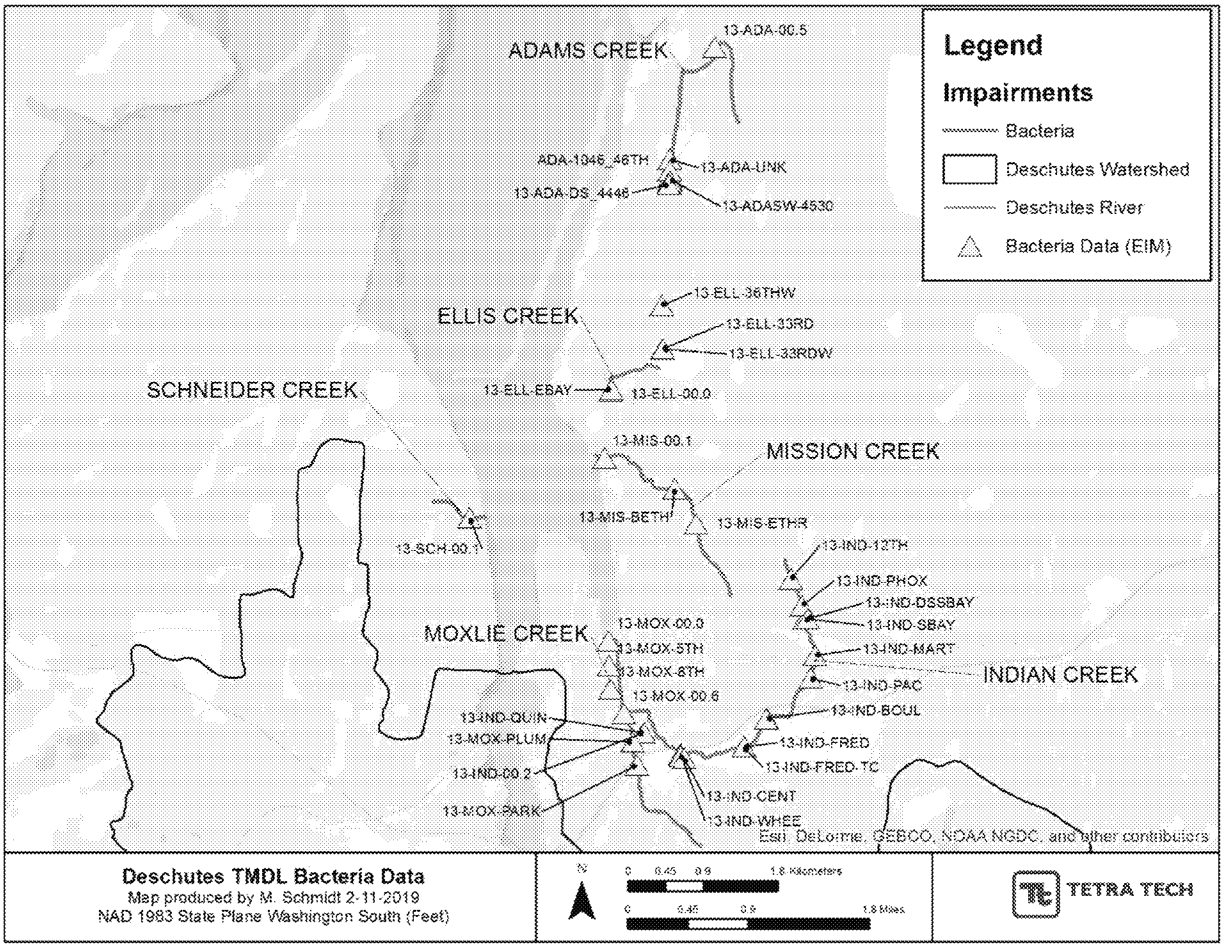


Figure [SEQ Figure * ARABIC]. EIM Bacteria Sampling Locations for Bacteria Impairments (Lower Deschutes)

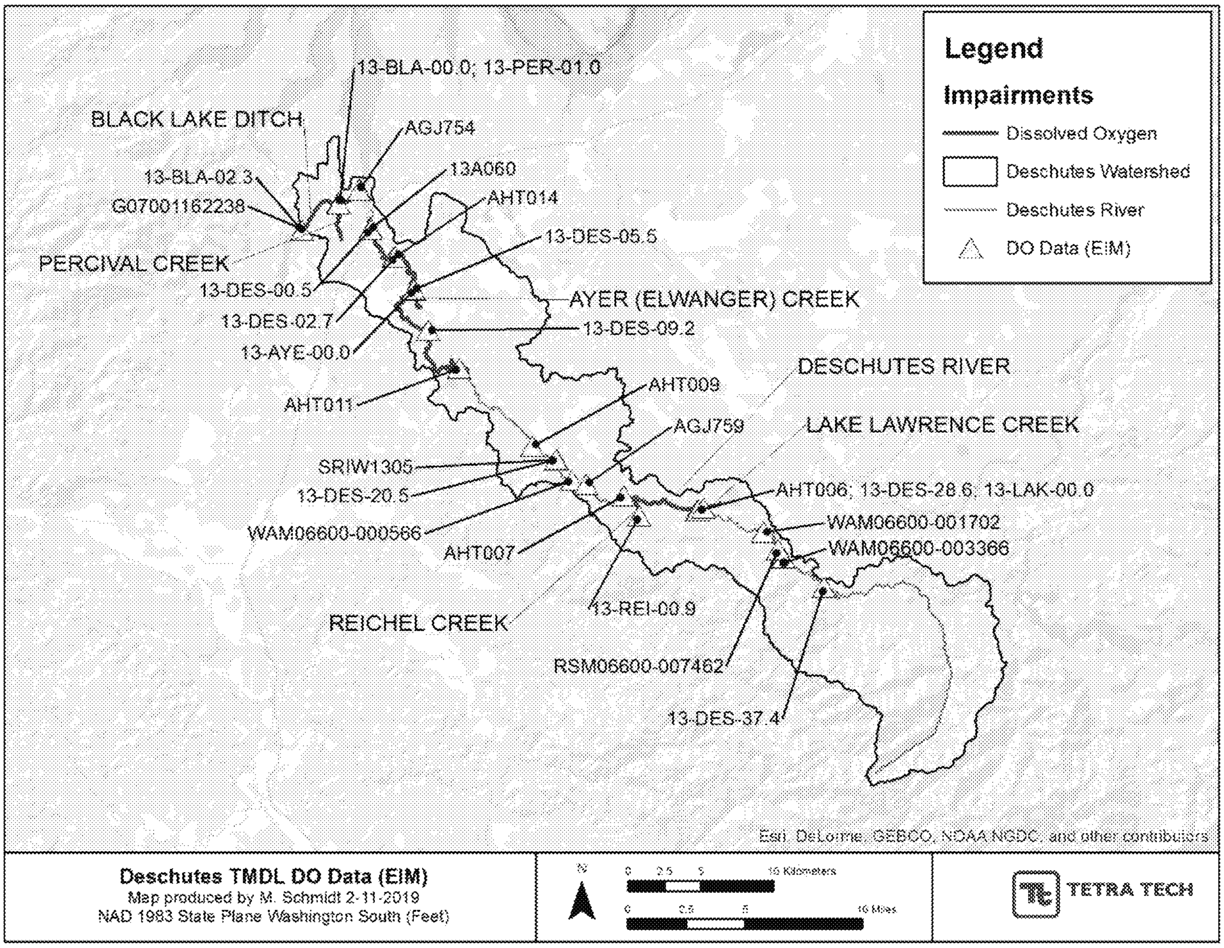


Figure [SEQ Figure * ARABIC]. EIM Dissolved Oxygen Sampling Locations for DO Impairments

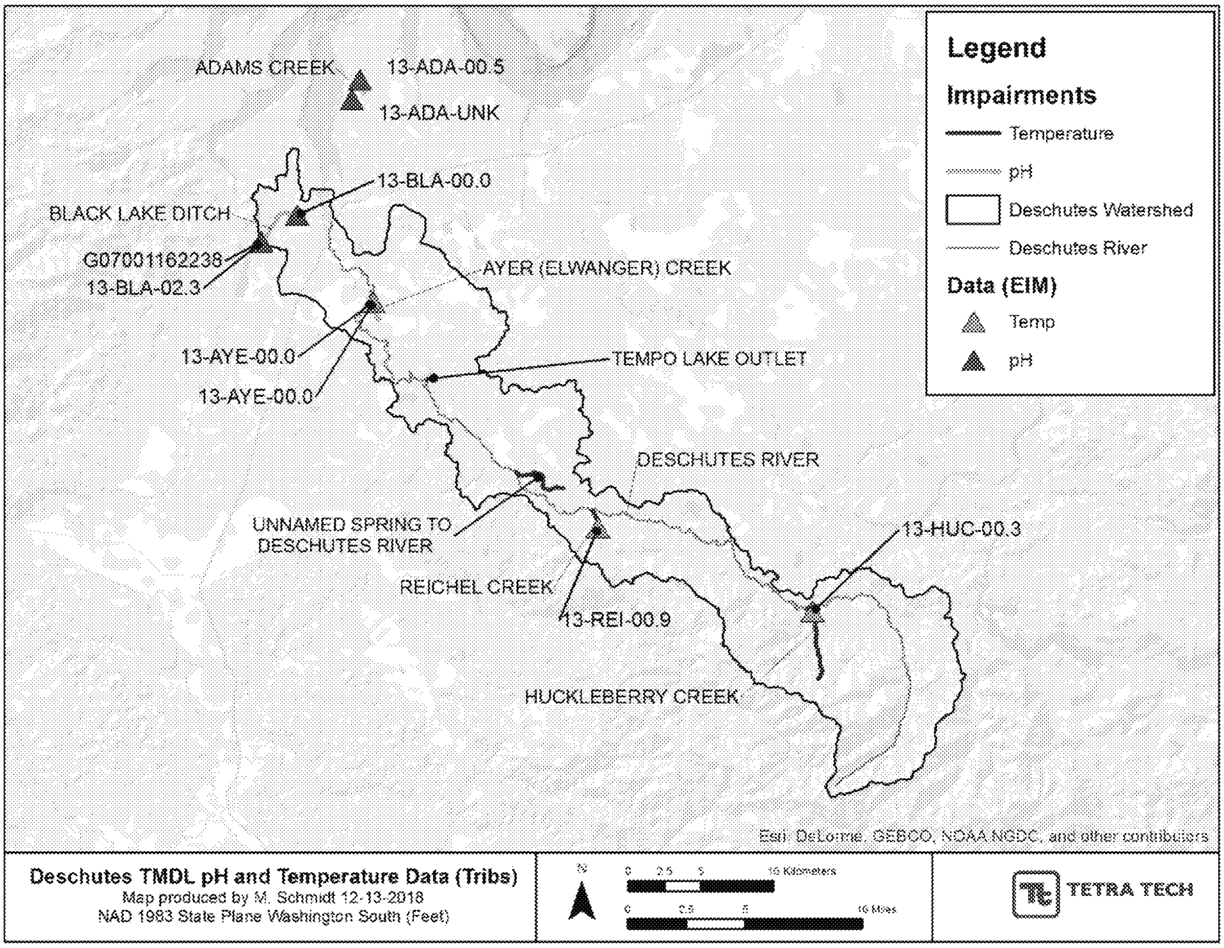


Figure [SEQ Figure * ARABIC]. EIM pH and Temperature Sampling Locations for Tributary pH and Temperature Impairments

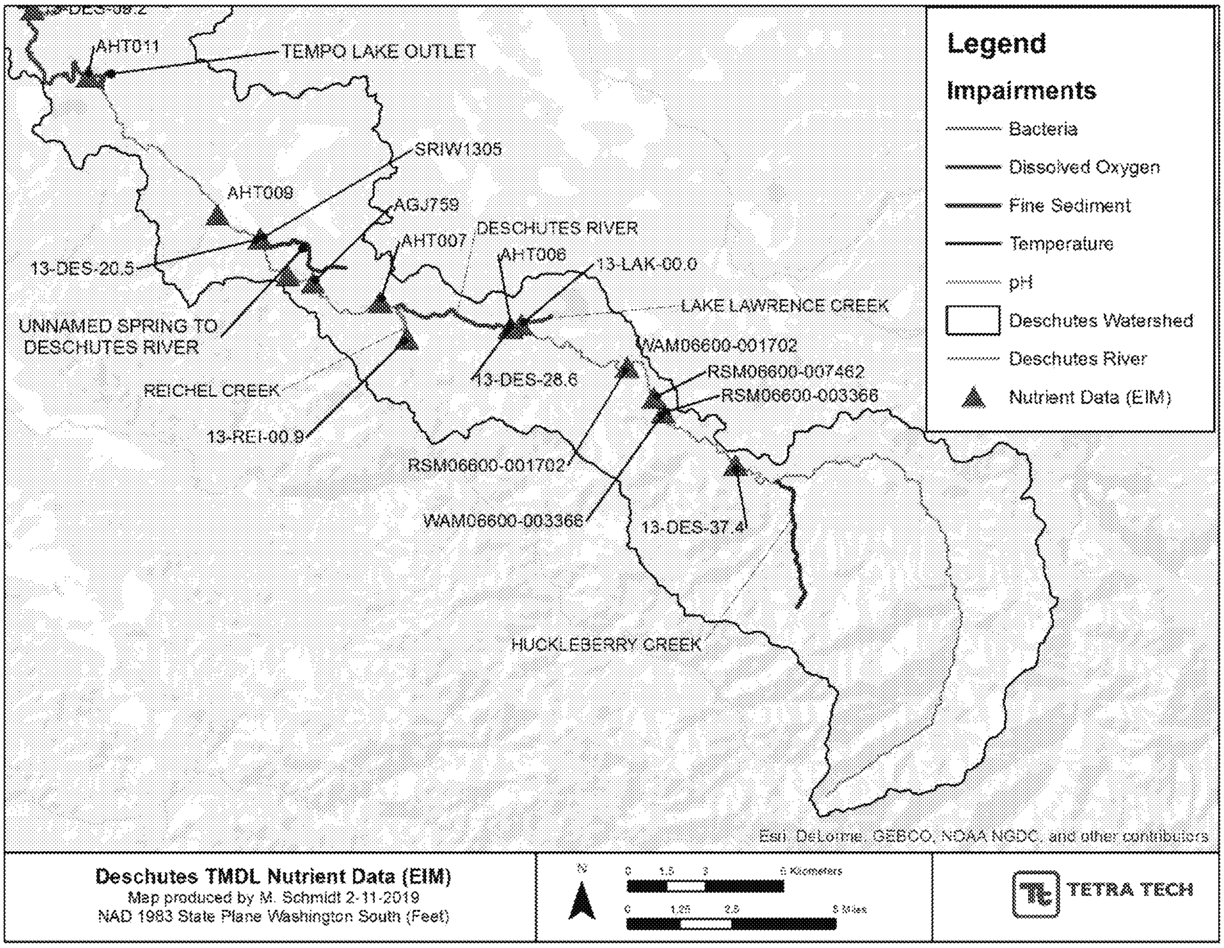


Figure [SEQ Figure * ARABIC]. EIM Nutrient Sampling Locations (Upper Deschutes)

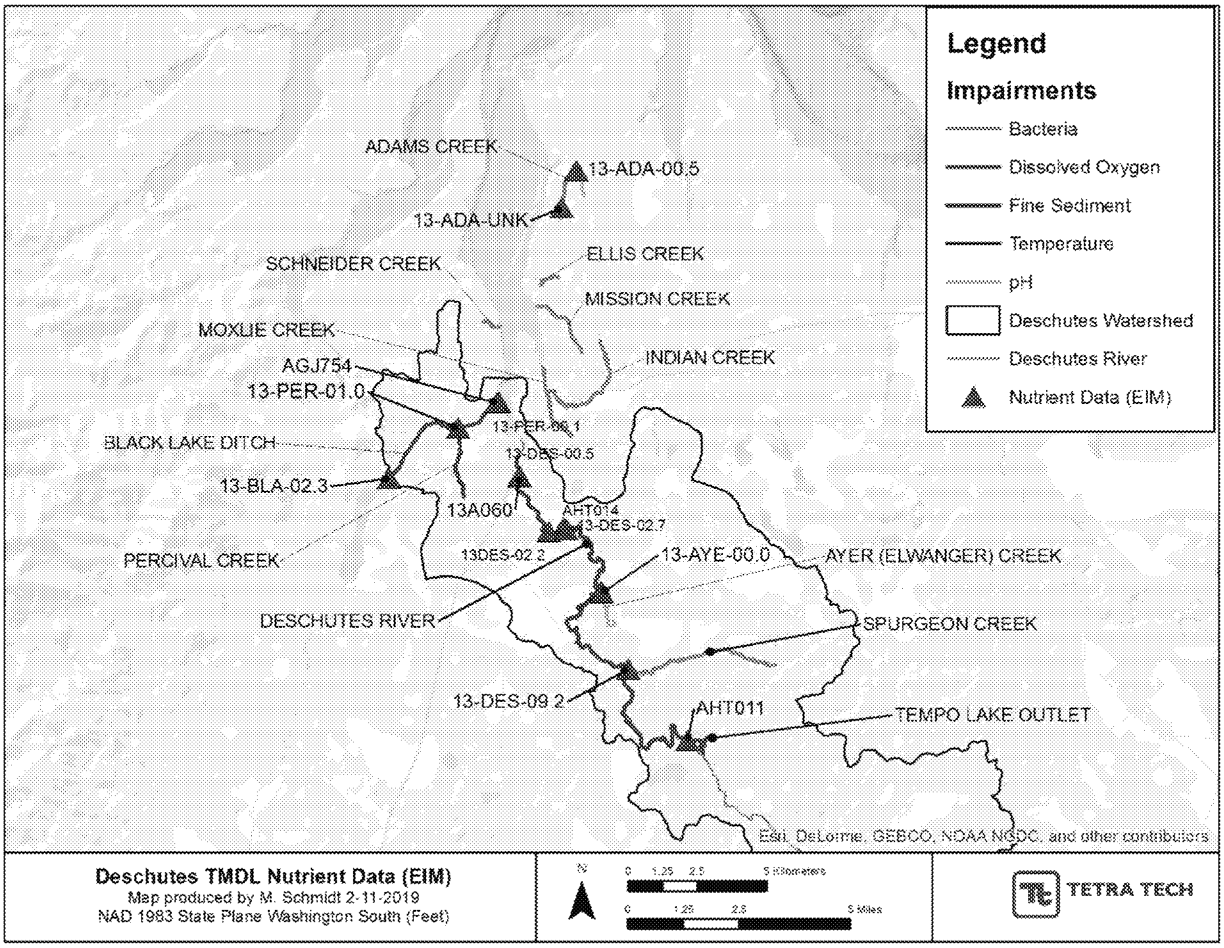


Figure [SEQ Figure * ARABIC]. EIM Nutrient Sampling Locations (Lower Deschutes)

Additional data sources were also reviewed as part of the preliminary data summary to inform the development of the technical approach and QAPP (Technical Direction for Phase I under EP-C-17-046 Task 0001) in accordance with Tetra Tech's (2016) *Quality Management Plan for Technical Support for Assessment and Watershed Protection*. Data housed in USEPA's Water Quality Portal, which replaces USEPA's STORET database, were extracted, mapped with ArcGIS, and reviewed. However, no additional data were available for the impaired segments through the Water Quality Portal that was not already available through other sources (e.g., EIM). Thurston County conducts routine water quality monitoring that is relevant to the TMDL. Thurston County provided their data in a spreadsheet format, which is summarized in [REF _Ref877881 \h].

Table [SEQ Table * ARABIC]. Summary of Surface Water Quality Data Collected by Thurston County

Waterbody	Number of Monitoring Events	Period of Record	Relevant Constituents Sampled
Black Lake Ditch	157	1/10/2005 – 9/13/2017	Water temperature, pH, DO, flow, TP, NOx
Indian Creek	172	7/27/1993 – 9/13/2017	Flow, fecal coliform
Moxlie Creek	246	1/29/1991 – 9/19/2017	Flow, fecal coliform
Reichel Creek	149	12/18/1990 – 9/11/2017	Water temperature, pH, DO, fecal coliform, flow, TP, NOx, NH4
Spurgeon Creek	207	12/18/1990 – 9/11/2017	Flow, fecal coliform
Deschutes River at Vail Rd.	128	1/26/1993 – 9/11/2017 (no data for critical modeling period of August 2004)	Water temperature, pH, DO, turbidity, flow, TP, NOx, NH4
Deschutes River at Waldrick Rd.	126	10/23/2007 – 9/11/2017 (no data for critical modeling period of August 2004)	Water temperature, pH, DO, turbidity, flow, TP, NOx, NH4
Deschutes River at Tumwater Falls Park	243	1/29/1992 – 9/11/2017 (no data for critical modeling period of August 2004)	Water temperature, pH, DO, turbidity, flow, TP, NOx, NH4

Several spatial coverages are needed to complete the spatial sheet and rill erosion modeling (RUSLE) for the Deschutes River fine sediment TMDL that are listed in [REF _Ref532374206 \h]. The rainfall-runoff erosivity factor represents the susceptibility to erosion due to local storm energy and intensity; it will be derived spatially across the watershed from the isoerodent map (i.e., rainfall-runoff erosivity factor) for Washington and Oregon developed by USEPA in 2001 (Figure 4-4d in Pitt, 2004). The soil erodibility factor quantifies erosion vulnerability due to physical soil traits that are available in a gridded format through the U.S. Department of Agriculture, Natural Resources Conservation Service gridded soil survey geographic database (gSSURGO). The length-slope (LS) factor represents the combined effects of slope steepness and slope length on erosion and it will be spatially derived from a 10-meter DEM. The erosion protection qualities of vegetative canopy, soil surface cover and roughness, and the impacts of low soil moisture are comprehensively represented through the cover-management factor, which will be approximated from remote sensing data (MODIS NDVI). Land management practices that limit erosion on cropland, such as contouring farming and terracing, can be represented with the support practice factor. Information regarding application of these practices in the watershed is uncertain, therefore, the practice (P) factor will be set uniformly to one (i.e., neutral impact on soil loss). A sediment delivery ratio (SDR) grid will also be developed to estimate the sediment loss from sheet and rill erosion that is delivered to the stream network. The Connectivity Index ToolBox in ArcGIS (Cavalli et al., 2013, 2014) will be used to generate the SDR grid from high-resolution elevation data. All the input grids will be scaled to the finest resolution (10 m) for modeling annual sediment loads.

Table [SEQ Table * ARABIC]. Gridded Data Sources for RUSLE Modeling

RUSLE Variable	RUSLE Factor	Data Source
R	Rainfall-Runoff Erosivity	Isoerodent Map for Washington and Oregon developed by EPA in 2001
K	Soil Erodibility	Gridded Soil Survey Geographic (gSSURGO) variable KFFACT (10 meter)
LS	Slope Length and Steepness	USGS National Elevation Dataset (10 meter DEM)
C	Cover-Management	MODIS Vegetation Indices, Normalized Difference Vegetation Index (NDVI) (16-day, 250 meter)
P	Support Practice	Assumed to be uniformly one.

Fine sediment data from past field studies will also be used. Percent fine sediment within riffle crests were sampled in the mid-1990s by Schuett-Hames and Child (1996) and in the mid-2000s by Konovsky and Puhn (2005; [REF _Ref877964 \h] and [REF _Ref877980 \h]). Sampling was conducted upstream (Lake Lawrence, Site 22) and downstream (State Route 507, Site 28) of the fine sediment impaired segment of the Deschutes River (Listing ID 6232). Data from these sites will be compiled to inform the needed percent reductions in fine sediment embedded in gravels of the Deschutes River TMDL. In addition, 285 turbidity samples collected from the Deschutes River ([REF _Ref856106 \h]) will be used to ensure that the turbidity standard is also met (described in Section IV.B.2).

Table [SEQ Table * ARABIC]. Deschutes River Fine Sediment Monitoring

Segment	River Mile Range	Fine Sediment Sample Count by Year		
		1995	2004	2005
Lake Lawrence (Site ID 22)	28.8 - 30.4	16	14	16
State Route 507 (Site ID 28)	20.8 - 24.4	18	14	18

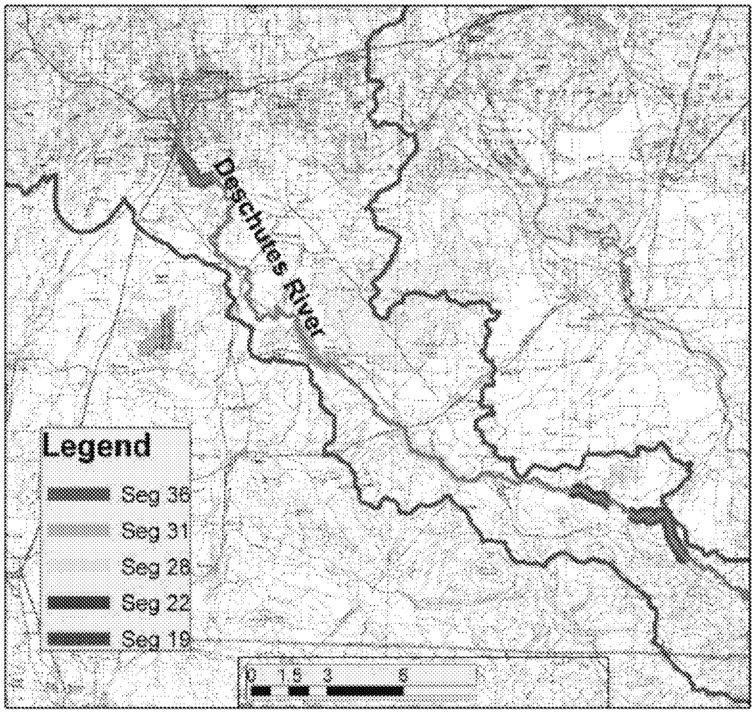


Figure [SEQ Figure * ARABIC]. Fine Sediment Study Reaches Sampled in 2004

Source: Konovsky and Puhn (2005). River kilometers (segment numbers) referenced from Deschutes Falls. Segment 22 corresponds with the fine sediment impairment of the Deschutes River.

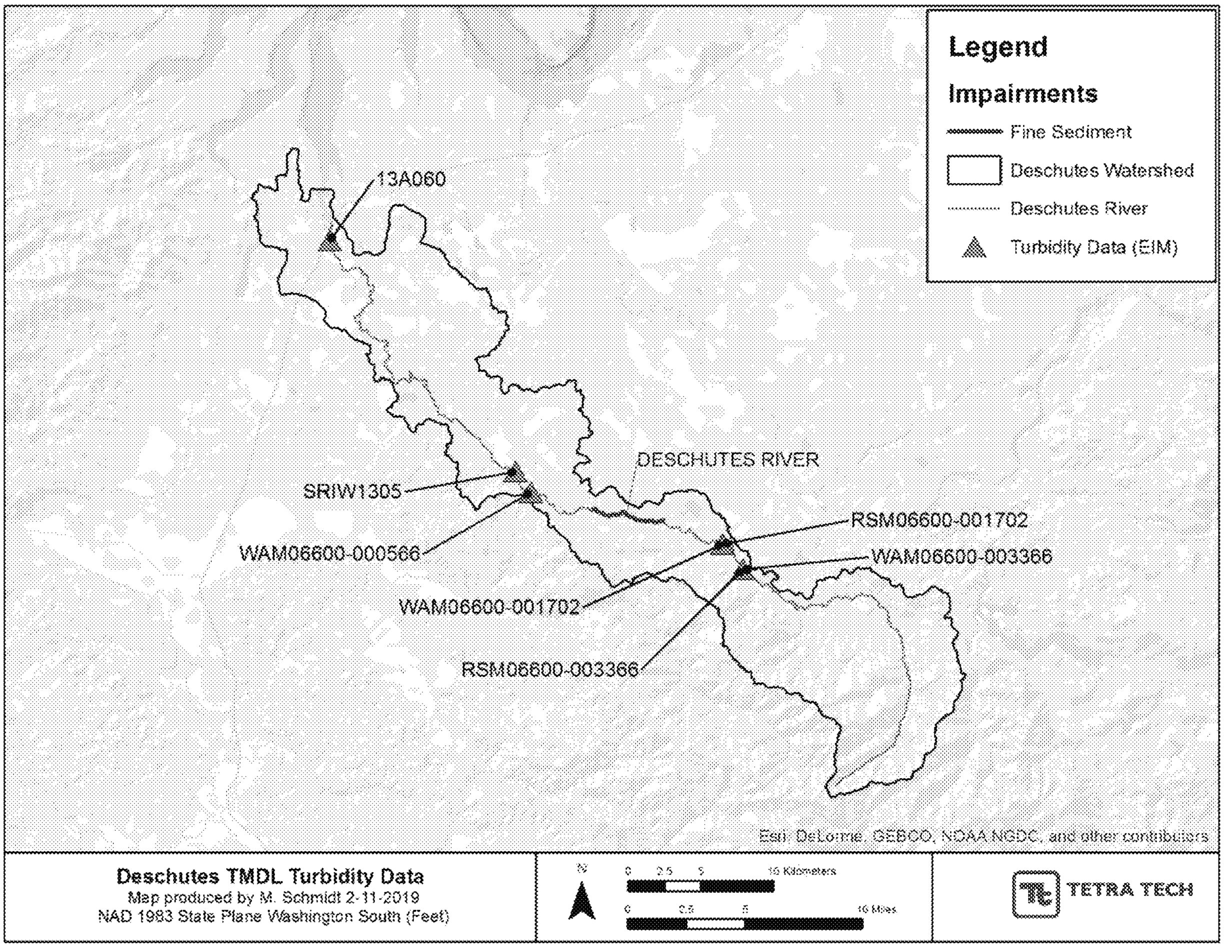


Figure [SEQ Figure * ARABIC]. EIM Turbidity Monitoring Sites for the Deschutes River

There are several other sources of secondary data that will be used for modeling and technical analyses as part of this project. Ecology maintains an online Water Quality Permitting and Reporting Information System (PARIS) that contains information about water quality permits and discharge monitoring data. However, there are no individual wastewater permits discharging to the impaired waterbodies. General permits for sand and gravel facilities and for construction in the watershed are downstream of the fine sediment impaired segment of the Deschutes River. Flow data from the United States Geological Survey (USGS) and from Washington's EIM database will also be applied ([REF _Ref855547 \h]; [REF _Ref855567 \h] - [REF _Ref855571 \h]). It is anticipated that meteorological data from the National Climatic Data Center (NCDC) for Olympia, Washington, or gridded historic weather data from NLDAS (North American Land Data Assimilation Systems) will be used to develop model weather inputs. LiDAR (LIght Distance And Ranging) data from the Puget Sound LiDAR Consortium will be used to develop inputs for the Shade models.

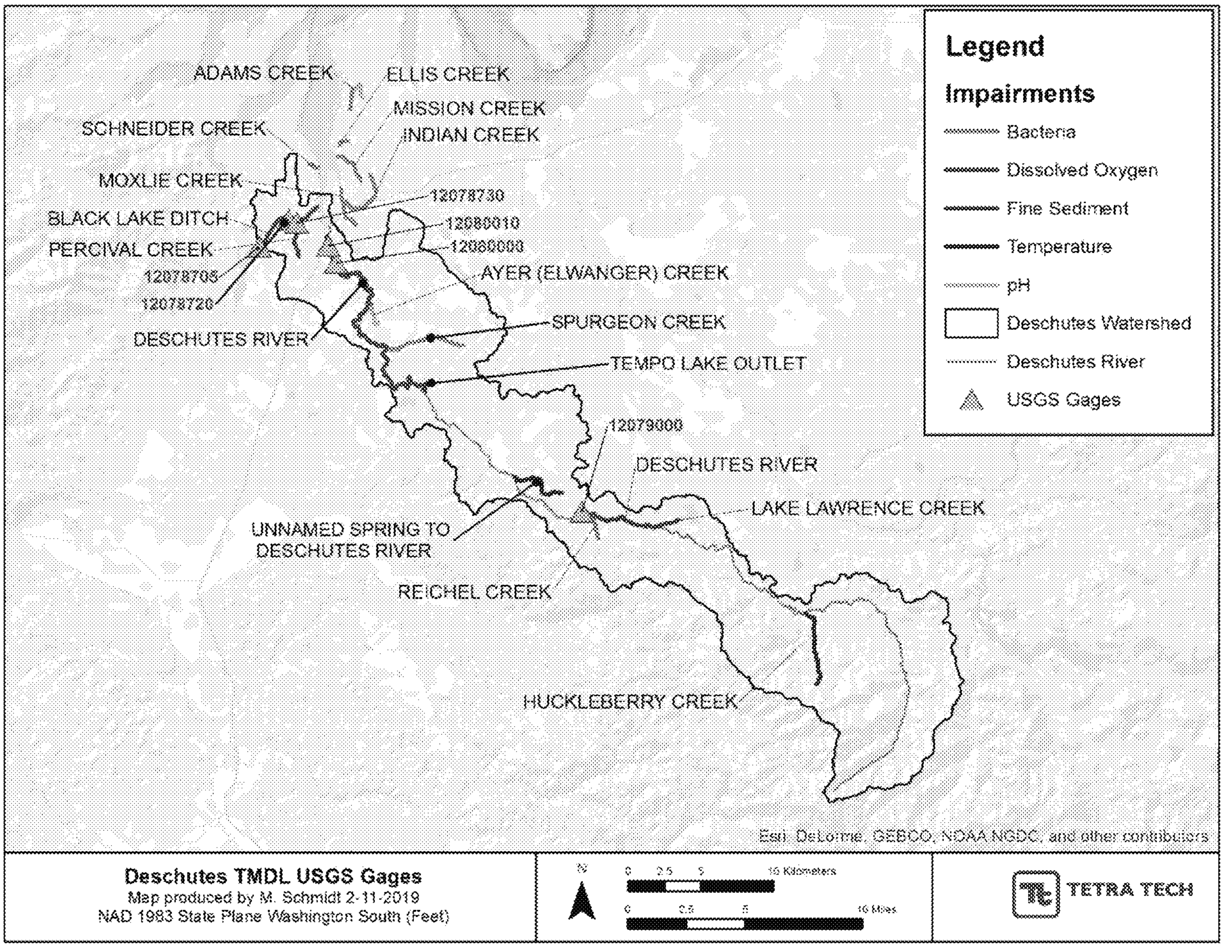


Figure [SEQ Figure * ARABIC]. USGS Flow Gages for the Deschutes TMDL

Table [SEQ Table * ARABIC]. Period of Record for USGS Flow Gages for the Deschutes TMLD

USGS Gage	Description	Period of Record
12078730	Percival Creek near Olympia, WA	3/1/1988 – 2/28/1990[a]
12078705	Black Lake Ditch at Lake Outlet near Tumwater, WA	2/22/1988 – 3/18/1990[a]
12078720	Black Lake Ditch at near Olympia, WA	2/23/1988 – 3/18/1990[a]
12080010	Deschutes River at E. Street Bridge at Tumwater, WA	10/1/1990 – 2/11/2019
12080000	Deschutes River near Olympia, WA	5/1/1945 – 6/30/1964[a]
12079000	Deschutes River near Rainier, WA	10/6/1987 – 2/11/2019

[a] It is not anticipated that these gages will be used in the TMDL because the period of record ended more than 25 years ago.

Table [SEQ Table * ARABIC]. EIM Flow Monitoring Sites for the Deschutes River

Waterbody	Site ID	Latitude	Longitude	Period of Record
Deschutes River	13A060	47.01176	-122.903	01/24/2000 - 09/26/2016
Deschutes River	RSM06600-018890	46.99539	-122.882	08/26/2015 - 08/26/2015
Deschutes River	13-DES-09.2	46.9504	-122.849	01/14/2004 - 12/28/2004
Deschutes River	13DES13.4	46.9276	-122.82	06/06/2003 - 09/23/2003
Deschutes River	13DES00.5	47.01176	-122.903	06/06/2003 - 08/05/2003
Deschutes River	13DES09.2	46.94982	-122.849	06/06/2003 - 09/23/2003
Deschutes River	13DES06.8	46.96621	-122.878	06/06/2003 - 08/05/2003
Deschutes River	13DES02.7	46.9951	-122.88	06/06/2003 - 09/23/2003
Deschutes River	13DES05.6	46.97482	-122.864	08/05/2003 - 09/23/2003
Deschutes River	WAM06600-000566	46.86054	-122.716	07/15/2009 - 07/19/2013
Deschutes River	WAM06600-003366	46.81618	-122.524	07/16/2009 - 07/20/2013
Deschutes River	RSM06600-003366	46.81618	-122.524	01/21/2015 - 12/01/2015
Deschutes River	RSM06600-001702	46.83163	-122.543	01/22/2015 - 12/01/2015
Deschutes River	RSM06600-007462	46.82126	-122.529	08/31/2015 - 08/31/2015
Deschutes River	13-DES-20.5	46.873	-122.731	01/14/2004 - 12/28/2004
Deschutes River	13DES32.3	46.83099	-122.547	06/03/2003 - 09/24/2003
Deschutes River	13DES24.9	46.85205	-122.669	06/06/2003 - 09/25/2003
Deschutes River	13DES28.6	46.844	-122.603	06/06/2003 - 09/23/2003
Deschutes River	13DES19.1	46.88093	-122.752	06/06/2003 - 09/25/2003
Deschutes River	13DES14.5	46.92065	-122.81	06/06/2003 - 08/05/2003
Deschutes River	13DES42.3	46.80192	-122.409	06/17/2003 - 09/23/2003
Deschutes River	13DES37.4	46.7986	-122.487	08/05/2003 - 08/05/2003
Deschutes River	13DES25.8	46.84942	-122.654	08/05/2003 - 08/05/2003
Deschutes River	WAM06600-001702	46.83163	-122.543	08/18/2009 - 09/10/2009

Table [SEQ Table * ARABIC]. EIM Flow Monitoring Sites for Impaired Tributaries

Waterbody	Site ID	Latitude	Longitude	Period of Record
Adams Creek	13-ADA-UNK	47.0993	-122.887	04/05/2004 - 04/07/2005
Adams Creek	13-ADA-DS_4530	47.09744	-122.887	02/08/2005 - 03/28/2005
Adams Creek	13-ADA-US_4510	47.09665	-122.887	02/08/2005 - 04/07/2005
Adams Creek	13-ADA-00.5	47.1115	-122.88	07/01/2003 - 03/29/2005
Ayer Creek	13-AYE-00.0	46.9748	-122.863	09/02/2003 - 03/29/2005
Black Lake Ditch	13BLA02.3	47.00972	-122.965	06/20/2003 - 08/06/2003
Black Lake Ditch	13BLA00.0	47.02712	-122.933	06/20/2003 - 09/23/2003
Black Lake Ditch	13BLD00.4	47.0275	-122.938	07/14/2004 - 09/08/2004
Black Lake Ditch	13BLD00.0	47.02712	-122.933	07/14/2004 - 09/08/2004
Black Lake Ditch	13BLA01.5	47.01932	-122.956	08/06/2003 - 08/06/2003
Black Lake Ditch	13-BLA-00.0	47.02712	-122.933	10/21/2003 - 11/03/2003
Ellis Creek	13-ELL-EBAY	47.07429	-122.895	03/28/2005 - 03/28/2005
Ellis Creek	13-ELL-33RDW	47.07881	-122.887	03/28/2005 - 03/28/2005
Ellis Creek	13-ELL-36THW	47.0835	-122.888	03/28/2005 - 03/28/2005
Ellis Creek	13-ELL-00.0	47.0741	-122.895	07/21/2003 - 03/29/2005
Ellis Creek	13-ELL-33RD	47.0788	-122.887	10/12/2004 - 03/29/2005
Ellis Creek	SPS ELLI CK	47.07446	-122.895	07/09/2007 - 10/10/2007
Indian Creek	13-IND-QUIN	47.03737	-122.888	07/03/2008 - 11/07/2008
Indian Creek	13-IND-CENT	47.03478	-122.882	07/03/2008 - 11/07/2008
Indian Creek	13-IND-BOUL-TC	47.03929	-122.869	07/03/2008 - 11/07/2008
Indian Creek	13-IND-00.2	47.0374	-122.888	07/21/2003 - 03/29/2005
Indian Creek	INDIAN-2	47.03743	-122.889	04/14/2010 - 04/24/2013
Indian Creek	INDIAN-1	47.03671	-122.871	04/21/2010 - 04/24/2013
Indian Creek	13-IND-MART	47.0463	-122.862	12/07/2004 - 12/08/2004
Indian Creek	13-IND-12TH	47.0544	-122.866	12/07/2004 - 12/07/2004
Lake Lawrence Creek	13-LAK-00.0	46.8455	-122.597	09/03/2003 - 10/13/2004
Mission Creek	13-MIS-00.1	47.0669	-122.896	07/21/2003 - 03/29/2005
Mission Creek	13-MIS-ETHR	47.0601	-122.881	12/07/2004 - 03/29/2005
Mission Creek	13-MIS-BETH	47.0638	-122.885	12/07/2004 - 03/29/2005

Waterbody	Site ID	Latitude	Longitude	Period of Record
Mission Creek	SPS MISS CK	47.06716	-122.896	07/09/2007 - 10/10/2007
Moxlie Creek	13-MOX-00.6	47.0394	-122.892	08/04/2003 - 03/29/2005
Moxlie Creek	SPS MOXL CK	47.0394	-122.892	07/09/2007 - 10/10/2007
Percival Creek	13-PER-54TH	47	-122.929	03/29/2005 - 03/29/2005
Percival Creek	13PER03.3	46.99982	-122.929	07/18/2003 - 09/08/2004
Percival Creek	13PER02.4	47.01102	-122.932	07/14/2004 - 09/08/2004
Percival Creek	13PER02.0	47.01642	-122.932	07/14/2004 - 09/08/2004
Percival Creek	13PER00.9	47.02722	-122.932	07/14/2004 - 09/08/2004
Percival Creek	13PER01.0	47.0269	-122.933	08/06/2003 - 07/14/2004
Percival Creek	13PER01.6	47.02093	-122.931	07/14/2004 - 09/08/2004
Percival Creek	13PER00.1	47.03546	-122.915	07/18/2003 - 09/08/2004
Percival Creek	13-PER-00.1	47.0356	-122.914	09/22/2003 - 10/21/2003
Reichel Creek	13-REI-00.9	46.8397	-122.655	10/07/2003 - 12/28/2004
Schneider Creek	13-SCH-00.1	47.06	-122.917	07/21/2003 - 12/28/2004
Spurgeon Creek	13-SPU-00.0	46.9502	-122.847	09/02/2003 - 03/29/2005
Spurgeon Creek	13-SPU-MOOD	46.9512	-122.834	03/29/2005 - 03/29/2005
Spurgeon Creek	13SPU00.0	46.9502	-122.847	07/03/2003 - 09/23/2003
Tempo Lake Outlet	13TEM00.0	46.92802	-122.812	07/01/2003 - 09/23/2003
Unnamed Spring to Deschutes	13SPI00.1	46.87252	-122.729	07/01/2003 - 08/05/2003

V.D.1 Quality Control for Nondirect Measurements

Most of the nondirect measurements will be obtained from quality assured sources. Tetra Tech will assume that data obtained from peer-reviewed papers, USEPA, National Oceanic and Atmospheric Administration (NOAA), USGS, USDA, and Ecology documents and databases have been screened and meet measurement performance criteria specified for the document or database unless there is evidence to the contrary. Where performance criteria are not reported for the parameters of interest in the documents or databases, Tetra Tech will determine how much effort should be made to find reports or metadata that might contain that information. Tetra Tech will perform general quality checks on the transfer of data from any source databases to another database, spreadsheet, or document.

Where data are obtained from sources lacking an associated quality report, Tetra Tech will evaluate data quality of such secondary data before using it. Additional methods that might be used to determine the quality of secondary data are

- Verifying values and extracting statements of data quality from the raw data, metadata, or original final report
- Comparing data to a checklist of required factors (e.g., analyzed by an approved laboratory, used a specific method, met specified data quality objectives, validated)

If it is determined that such searches are not necessary or that no quality requirements exist or can be established, but the data must be used in the task, Tetra Tech will add a disclaimer to the deliverable indicating that the quality of the secondary data is unknown.

V.D.2 Treatment of Censored Data (Non-Detects)

Environmental data sets frequently contained laboratory data analyses that are censored or reported as non-detects. Censoring may be reported in relation to an instrument detection limit (IDL, the minimum concentration of an analyte that can be reported by an instrument), a method detection limit (MDL, the minimum concentration of an analyte that can be measured and. reported with 99% confidence that the analyte concentration is greater than zero) or a practical quantitation limit (PQL, the minimum concentration of an analyte (substance) that can be measured with a high degree of confidence that the analyte is present at or above that concentration). Censored data contain information, albeit imprecise, and should not be ignored; however, censored data also present significant challenges for inclusion in numerical or statistical analyses.

In the past, it has sometimes been the practice to include censored data in analyses at one-half the reported limit (or, sometimes, at the limit to be conservative). This approach, while simple, is not statistically valid and can lead to biased results (Helsel, 2005). The choice of a valid approach depends in part on the intended uses of the data.

It is anticipated that only the bacteria datasets (fecal coliform and enterococci) will require treatment of censored data. In general, we will rely on the methods reported in Helsel (2005) and implemented in the NADA R statistical package (Lee, 2017) for methods incorporating censored data. The appropriate methods described in Helsel (2005), as supplemented by Bolks et al. (2014) will be applied to analysis of censored data for all pollutants and will be documented in a memorandum that will be circulated to obtain agreement from USEPA, as well as included in the final technical report.

V.E TIME FRAME OF SIMULATION

The selection of the simulation period for each QUAL2Kw model will be based on availability of monitoring records that can be used for calibration and evaluation. If USEPA decides to complete QUAL2Kw modeling for the impaired tributaries, Tetra Tech will evaluate the monitoring data, propose a critical period for each impaired tributary, and confirm the critical period with USEPA. Each QUAL2Kw model will simulate diel water quality kinetics under steady-state flow in one-dimensional reaches with hourly inputs for headwater boundary conditions, weather variables, and shade. The critical period previously defined by Ecology for the Deschutes River model was mid-August 2004, and it is anticipated that this will be maintained as the critical assessment period. Most of the available monitoring data to support model calibration and evaluation efforts for the temperature, pH, and DO impaired tributary creeks is also from 2004. Therefore, it is anticipated that the calibration periods for the tributary QUAL2Kw models will be in 2004, but this will be confirmed with USEPA.

The time frame of assessment for the bacteria impaired segments will be based on the data record used to develop the Load-Duration Curves. The primary data collection period for the bacteria impaired segments was in the mid-2000s (mostly in 2003-2004). Available bacteria data will be paired with long-term daily flow records from the Deschutes River at Tumwater USGS gage (anticipated period is 2008-2018) scaled based on relative drainage area.

V.F DATA GAPS

While some data have been collected since the original assessment and submission of the TMDL, data gaps and limitations remain present. For example, no relevant bacteria monitoring has been conducted in the past ten years and the technical analyses will need to rely on data from the mid-2000s. Furthermore, long-term flow records are not available for the bacteria impaired creeks. To address this data gap, flows will be approximated by scaling flow records from the Deschutes River. Two of the bacteria impaired creeks drain to Inner Budd Inlet, which is subject to an enterococci standard, but no enterococci data are available for these creeks. Target loading capacities for enterococci will still be developed based on the Inner Budd Inlet criteria.

There are only three DO samples available for the DO impaired Lake Lawrence Creek. A fair amount of DO data is available for the impaired segments of the Deschutes River. However, only two chlorophyll *a* samples are available to provide important information about algae in the stream that contribute to DO fluctuations through respiration and photosynthesis. Diel DO cycling due to algae photosynthesis and respiration will inform the representation of algae in the river model.

There are spatial and temporal data gaps for the DO, pH, and/or temperature impaired tributary streams. In general, data is available at either the upstream or the downstream end of the impaired segment. Therefore, longitudinal changes in conditions in the waterbody remain uncertain (e.g., decreasing DO along the length of the impaired segment). Monitoring of the impaired tributaries was typically done with grab samples collected a couple of times on any single day that may not correspond with critical points in the diel cycle (e.g., minimum and maximum daily DO concentration). A comprehensive understanding of diel cycling, therefore, remains uncertain. Monitoring times will be used to assess if the full diel cycle is represented (e.g., minimum DO typically occurs around daybreak following nighttime respiration by algae).

Lastly, the loading capacity defined for the fine sediment TMDL for the Deschutes River will also need to meet turbidity requirements. However, no turbidity data are available for the fine sediment impaired segment. Nevertheless, turbidity will be evaluated using a regionally derived suspended sediment to turbidity regression and turbidity data from upstream and downstream of the impaired segment.

Given the current state of data gaps, key sensitivities and uncertainties will be assessed through model applications. Relevant information from the literature will be applied to address data gaps where possible and useful (e.g., regional ambient nutrient concentration may be used where data are unavailable). These assumptions, and those required to be based on best professional judgement, will be documented in the technical report.

V.G IMPORTANT ASSUMPTIONS

Water quality models can be viewed as a combination of theory, observations, and assumptions that represent a "best available understanding" of a waterbody. The model software incorporates the mathematical equations from the peer-reviewed literature in water quality science, and the calculations are driven by the available data for the study area. The model is rounded out by numerous assumptions and troubleshooting in the setup, calibration, and evaluation process.

Assumptions will need to be made where data are spatially or temporally unavailable. For example, assumptions will be necessary for characterizing channel geometry for the tributaries and some boundary conditions of the QUAL2Kw models (e.g., flows and water quality conditions for the headwaters, tributaries, and diffusive inflows). Information from past studies, similar sites, and information from peer-reviewed guidance documents related to water quality modeling (e.g., expected reaeration rates, sediment oxygen demand) will be combined with best professional judgement when making important assumptions.

Other key assumptions made during the collection, handling, transformation (harmonizing format and terms for compilation), and incorporation of data into the existing model will be discussed with the USEPA Task Order Contracting Officer's Representative (TOCOR) and USEPA Technical Leads, as appropriate, and will be documented in the draft and final technical memorandum, and/or model files.

V.H MODEL CALIBRATION

Environmental simulation models are simplified mathematical representations of complex real-world systems. Models cannot accurately depict the multitude of processes occurring at all physical and temporal scales. Models can, however, make use of known interrelationships among variables to predict how a given quantity or variable would change in response to a change in an interdependent variable or forcing function. In this way, models can be useful frameworks for investigations of how a system would likely respond to a perturbation from its current state. To provide a credible basis for prediction and the evaluation of mitigation options, the ability of the model to represent real world conditions should be demonstrated through a process of model calibration and corroboration (CREM, 2009).

Model calibration is designed to ensure that the models are adequate to examine stressor-response relationships and to define critical components of the TMDLs. The QUAL2Kw modeling will form the initial basis for identifying the TMDL allocations for achieving standards in the temperature, pH, and DO impaired creeks.

Calibration consists of the process of adjusting model parameters to provide an appropriate representation of observed conditions and underlying processes. Calibration is necessary because of the semi-empirical nature of water quality models. Although these models are formulated from mass balance principles, most of the kinetic descriptions in the models are empirically derived. These empirical derivations contain a number of coefficients that are usually determined by calibration of the model to observed water quality data that have been collected in the waterbody of interest.

Calibration tunes the models to represent conditions appropriate to the waterbody and watershed under study. However, calibration alone is not sufficient to assess the predictive capability of the model, or to determine whether the model developed via calibration contains a valid representation of cause and effect relationships, especially those associated with the principal study questions. To help determine the adequacy of the calibration and to evaluate the uncertainty associated with the calibration, the model is subjected to a validation or corroboration step. The terminology of corroboration is preferred by CREM (2009), and "includes all quantitative and qualitative methods for evaluating the degree to which a model corresponds to reality. The rigor of these methods varies depending on the type and purpose of the model application." In a traditional validation step, the model is applied to a set of data independent from that used in calibration to test its performance. However, the reality is that the "validation" test often indicates the need for further adjustments, resulting in an iterative process, potentially followed by another validation test.

The QUAL2Kw models to be developed for the impaired tributaries are steady-state (but diurnally variable), critical-condition models. Tetra Tech will identify a period of relatively intensive data availability from the existing monitoring record for calibration, corroboration, and potential further testing of the model performance. Following the calibration, critical conditions will be simulated for the TMDL assessment (e.g., simulation of lower inflows, warmer air temperatures). A critical period in August 2004 was defined by Ecology for the Deschutes River QUAL2Kw model that will be maintained. The inputs and existing calibration will be reviewed by Tetra Tech. If refinements to the build and parameterization of the model are warranted the calibration may be refined. If no changes to the build and parameterization are necessary, then the calibrated critical conditions model will be applied directly for subsequent analyses.

The tributary models (and potentially the Deschutes River model should improvements to the model setup and/or parameters be needed) will be calibrated through a sequential process, beginning with the flow balance and hydrology, followed by water temperature, chemical water quality, and algal/macrophyte response.

The simulated water balance is determined almost entirely by boundary conditions, which will be specified based on best available data. The calibration of hydrology in QUAL2Kw is focused on ensuring that depths, flow velocities, and travel times are well-represented in the model.

The temperature simulation will depend on boundary conditions and riparian shading; Shade models will be built to inform the riparian shading parameterization.

The water quality calibration will begin by attaining a general representation of total N and total P concentrations. This will be followed by calibration for nutrient species, which must be done simultaneously with model development of macrophyte growth. For the macrophytes (e.g., *Elodea*), the model representation of benthic algae will serve as a surrogate. This may require reducing the sensitivity of the "attached algae" in the model to water column phosphorus concentrations, as *Elodea* can obtain phosphorus via its roots from the sediment. Dissolved oxygen and pH calibration then occurs as the final step, as the DO balance depends on all the other components of the calibration.

After the model is adequately calibrated, the quality of the calibration will be further evaluated through corroboration tests on additional data sets. In the past, this has typically been described as a validation test, where model validation is defined as, "subsequent testing of a pre-calibrated model to additional field data, usually under different external conditions, to further examine the model's ability to predict future conditions" (USEPA, 1997). In fact, extension of the model to new data sets often requires some further adjustments and assumptions, resulting in an iterative process of model development that is more appropriately termed corroboration. The corroboration step helps to ensure that the calibration is robust, and that the quality of the calibration is not an artifact of over-fitting to a specific set of observations. Corroboration tests can also provide evidence as to the degree of uncertainty that may be expected when the model is applied to conditions outside of the calibration series.

It is unreasonable to expect that the model will exactly predict all spatial and temporal variations in concentrations. Therefore, it is important to evaluate the water quality calibration through use of statistical tests of equivalence between observed and simulated data in addition to qualitative graphical comparisons.

To conduct the calibration and validation process, a set of basic statistical methods will be used to compare model predictions and observations for average, minimum, and maximum DO, pH, nutrient concentrations, and temperature, including the mean error statistic, the absolute mean error, the root-mean-square error, and the relative error. Because QUAL2Kw is a steady-state (diurnal) model, other statistics that are commonly applied to dynamic models, such as the coefficient of determination, and the Nash-Sutcliffe coefficient of model fit efficiency, will not be applied here.

Mean Error Statistic. The mean error between model predictions and observations is defined as

[EMBED Equation.3],

where

E = mean error

O = observations

P = model prediction at the same time as the observations

n = number of observed-predicted pairs

A mean error of zero is ideal. A non-zero value is an indication that the model might be biased toward either over- or under-prediction. However, an important consideration of the mean error approach is that it can severely penalize the model for small phase shifts in timing. One approach that can be used to address this is to establish a time window, calculate the range of model predictions for the time window, then count a deviation from prediction only if the observation falls outside this range.

Absolute Mean Error Statistic. The absolute mean error between model predictions and observations is defined as

[EMBED Equation.3],

where

E_{abs} = absolute mean error.

An absolute mean error of zero is ideal. The magnitude of the absolute mean error indicates the average deviation between model predictions and observed data. Unlike the mean error, the absolute mean error cannot give a false zero.

Root-Mean-Square Error Statistic. The root-mean-square error (E_{rms}) is defined as

[EMBED Equation.3],

A root-mean-square error of zero is ideal. The root-mean-square error is an indicator of the deviation between model predictions and observations. The E_{rms} statistic is an alternative to (and is usually larger than) the absolute mean error.

Relative Error Statistics. The relative error statistics (*RE*) between model predictions and observations can be calculated by dividing the mean error and absolute mean error statistics by the mean of the observations. A relative error statistic of zero is ideal. When it is non-zero, it represents the percentage of deviation between the model prediction and observation.

The quantification metrics described above are not appropriate where data is limited (e.g., single grab sample for a constituent during the model period). For cases of limited data, the model performance will primarily be evaluated with visual plots that compare simulated and observed variables.

V.I MODEL PARAMETERS

The modeling approach described above in Section IV includes two process-based models. The QUAL2Kw model will be the primary tool for simulating dissolved oxygen, temperature, pH, and algae, while the RUSLE model and accompanying connectivity-based SDR analysis.

QUAL2Kw models have already been developed for the Deschutes River by Ecology, focusing on dissolved oxygen and temperature. Parameter values in these existing models will provide the starting point for additional QUAL2Kw development. Modifications to these parameters will likely occur during model calibration. Additional information may be needed to address the algal growth component, which was not a focus of the prior effort. Only limited guidance on acceptable ranges of parameters is provided in the QUAL2Kw documentation. However, we are aware of an ongoing effort by USEPA ORD/NERL to develop a guidance document "Literature Review on Nutrient-Related Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling" that summarizes parameters in existing applications of QUAL2Kw models. While this document is not yet citable, we propose to make use of the unpublished findings therein to help constrain reasonable ranges of QUAL2Kw model parameters. We will also make use of examples from other QUAL2Kw model applications completed under QAPPs in Washington, Oregon, and Montana (e.g. Wenatchee, Yellowstone, Bear-Evans, North Fork Palouse, Umpqua) to help guide parameter ranges.

Parameters for the RUSLE upland sediment erosion model (specified on a gridded basis) are largely available from soil surveys and digital elevation models and are not modified during calibration. Parameter inputs will build on equations and recommendations found in the RUSLE's user guide. The RUSLE erosivity factor will be based on the Isoerodent Map for Washington and Oregon developed by EPA in 2001. The SDR approach of Vigiak et al. (2012) requires estimates of three calibration parameters, SDRmax, IC_0, and k. Vigiak et al. provide recommendations for optimum ranges of IC_0, and k, while SDRmax can be estimated as a function of average soil particle diameter.

SECTION VI: MODEL EVALUATION AND ACCEPTANCE

VI.A MODEL UNCERTAINTY AND SENSITIVITY

From a planning and management perspective, the primary function of the calibrated water quality models will be to predict the response of instream DO, pH, and/or temperature to changes in external loads and management. As such, an important input to the decision-making process is information on the degree of uncertainty that is associated with model predictions. In some cases, the risks, or costs, of not meeting water quality standards could be substantially greater than the costs of over-protection, creating an asymmetric decision problem in which there is a strong motivation for risk avoidance. Therefore, an uncertainty analysis of model predictions is essential.

As with any mathematical approximation of reality, a water quality model is subject to significant uncertainties. Direct information on the aggregate prediction uncertainty will arise from the model validation exercise; however, further diagnostics are needed to understand the sources and implications of uncertainty.

The major sources of model uncertainty include the mathematical formulation, boundary conditions data uncertainty, calibration data uncertainty, and parameter specification. In many cases, a significant amount of the overall prediction uncertainty is due to boundary conditions (e.g., uncertainty in estimation of ungaged tributary flows) and uncertainty in the observed data used for calibration and validation. These sources of uncertainty are largely unavoidable, but do not invalidate the use of the model for decision purposes. Uncertainties in the mathematical formulation and model parameters are usually of greater concern for decision purposes as these describe the cause and effect relationships in the calibrated model.

The QUAL2Kw model code has a long history of testing and application, so outright errors in the coding of the model are unlikely. A simulation model, however, is only a simplified representation of the complexities of the real world. The question is not whether the model is "right" in the sense that it represents all processes, but rather whether it is useful, in the sense that it represents the important processes to a sufficiently correct degree to be useful in answering the principal study questions.

The most widely applied parameter uncertainty analysis approach for complex simulation models is sensitivity analysis. Sensitivity analysis is implemented by perturbing model parameter values one at a time (or in combination) and evaluating the model response. This method is useful in identifying key parameters and processes in a water quality system, and the interpretation of the result is straightforward and meaningful. Sensitivity analysis, however, is limited in its ability to evaluate nonlinear interactions among multiple parameters.

VI.B MODEL ACCEPTANCE

For a model to be utilized in the development of TMDLs, NPDES permits, or other water program decision, the model must first be accepted by the regulatory agencies and stakeholders. The most common model development goals are (1) to minimize the difference between simulated and observed water quality and (2) to capture the spatial and temporal patterns in the observed water quality conditions. Progress toward achieving these goals is commonly captured in error statistics and graphical plots. However, model quality goes beyond these core evaluations. Several parallel tasks to achieve overall model quality are pursued alongside efforts to reduce model error, including:

1) Incorporation of all available observations of the system (e.g., geometry, flow, boundary inputs/withdrawals, and meteorology) for the time period simulated.
2) Reasonable estimation methods and assumptions to fill gaps in the observations.
3) Calibration of model parameters and unmeasured boundary conditions within reasonable bounds to improve agreement between simulated and observed water quality.
4) Identification of key parameters/processes through model calibration and sensitivity analysis.
5) Clear communication of key assumptions during model development with the project team.
6) Clear written documentation of important elements in the model, including model setup, boundary conditions, assumptions, and known areas of uncertainty.
7) Peer review.

Specific numeric acceptance criteria are not specified for the model. Instead, appropriate uses of the model will be determined by the project team based on assessment of the types of decisions to be made, the model performance, and the available resources.

SECTION VII: DOCUMENTATION IN MODEL REPORTS

Model updates, setup, and results will be documented in a series of technical memorandums that will be combined into a final technical report after model work has been completed. Tetra Tech will deliver the interim Draft Technical Memorandums for USEPA to review and provide comments. Tetra Tech will update the memorandums based on the USEPA comments and submit a comprehensive Final Technical Report.

The Tetra Tech Technical Lead, in coordination with the Tetra Tech TOL, will maintain a central project file in Tetra Tech's Research Triangle Park, North Carolina, office to contain all related documents, reports, communications, data compilations, checklists or other records, and deliverables (electronic files and hard copies). Electronic files and records will be stored on Tetra Tech's secure network, which is regularly backed up internally, and to an off-site server to preserve business continuity in the event of natural or other catastrophic events, which may result in local or regional catastrophic failure or disruption. The Tetra Tech TOL and Technical Lead will retain all files for a period of no less than five years after final delivery.

SECTION VIII: PEER REVIEW

The calibrated models and accompanying model report will be subject to third-party technical peer review at the discretion of the USEPA TOCOR or Technical Lead. It is anticipated that such reviews will include a technical review by staff from USEPA, Ecology, and/or USGS. Tetra Tech will provide a response to technical review comments and perform any needed modifications to the model and report.

SECTION IX: MANAGEMENT SCENARIOS

As discussed in the technical approach (Section IV), the TMDLs developed for these impaired waterbodies must also be protective of downstream water quality. Therefore, the management scenario to be explored through modeling for each impairment will be based on the most stringent water quality standard, either the standard directly applicable to the waterbody or the standard for the receiving waterbody.

The Deschutes River and Percival Creek currently drain to the man-made Capitol Lake.

Ex. 5 Deliberative Process (DP)

Ex. 5 Deliberative Process (DP) Point and nonpoint source inputs to the calibrated QUAL2Kw models will be adapted to represent natural conditions in the Deschutes River and Percival Creek. Adjustments to the models to represent the natural conditions will include restoration of shade with mature riparian vegetation, removal of thermal and oxygen-demanding pollutants from point source discharges, and restoration of natural surface and groundwater flow regimes and constituent concentrations. In addition, model rates, fluxes, and initial conditions will be set at values representative of natural conditions (e.g., rates of reaeration, SOD). Anthropogenic alterations to channel geometry, if any, will also be removed.

Ecology developed a natural condition scenario that set constituents to the 10th percentile of historical monitoring records. The assumptions made for the natural conditions scenario will be reviewed and updated based on information from relevant studies in the literature, such as the Natural Background Concentrations of Nutrients in Streams and Rivers of the Conterminous United States by Smith et al (2003); USEPA's Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion II published in 2000; and Analysis of Washington Nutrient and Biological Data (Periphyton) for the Nutrient Scientific Technical Exchange Partnership Program (Tetra Tech, 2018).

Ex. 5 Deliberative Process (DP)

It is also expected that USEPA will use the completed model results to assess the relative contribution of different pollutant sources to develop LAs and WLAs. If Tetra Tech receives Technical Direction to develop additional management scenarios for TMDL implementation this section of the QAPP will be expanded as an addendum.

SECTION X: PROJECT ORGANIZATION AND MANAGEMENT

X.A PROJECT TEAM ROLES

The project team, roles, and responsibilities for key technical and quality management functions, and lines of authority and communication are described in Section I, Subsection [REF _Ref490148515 \w \h], Roles and Responsibilities.

X.B EXPERTISE AND SPECIAL TRAINING REQUIREMENTS

Tetra Tech staff involved in developing model input data sets and model application have experience in numerical modeling gained through their work on numerous similar projects. The Tetra Tech Task Order Lead (TOL), Ms. Teresa Rafi, who has extensive experience managing similar projects, will provide project oversight. The TOL will ensure strict adherence to the project protocols.

The Tetra Tech QA Officer for this Task Order is Susan Lanberg, whose primary responsibilities include the following: providing oversight support to the Tetra Tech TOL in preparing the QAPP, reviewing and approving the QAPP, and, with the assistance of assigned QC Officers, monitoring QC activities to determine conformance with QA/QC requirements.

Michelle Schmidt will serve as the Tetra Tech Technical Lead. She has supported Region 10 in technical assessments for TMDL development and she has experience in watershed planning, water quality management, pollutant source identification and modeling, and environmental assessment. She has developed numerous watershed and receiving water models to support hydrologic and water quality studies for USEPA, state, and local governments across the county.

X.C REPORTS TO MANAGEMENT

This section identifies the role of senior management and key junctures of the project when the team will communicate progress and/or issues to agency management. In addition to communicating to management at key junctures, the project team should inform management of major deviations from the QAPP in a timely manner, such as delays in the model development schedule, changes in technical approach, and unforeseen data or model framework limitations.

The Tetra Tech TOL (or designee) will provide monthly progress reports to USEPA. As appropriate, these reports will inform USEPA of the following:

- Adherence to project schedule and budget
- Deviations from approved QAPP, as determined from project assessment and oversight activities
- The impact of any deviations on model application quality and uncertainty
- The need for and results of response actions to correct any deviations
- Potential uncertainties in decisions based on model predictions and data
- Data quality assessment findings regarding model input data and model outputs

X.D PROJECT SCHEDULE

The schedule for the initial phase of Water Quality Modeling and TMDL Development for Deschutes River, Percival Creek, and Budd Inlet Tributaries was described in Task Order 1 of contract EP-C-17-046 that spanned Ex. 5 Deliberative Process (DP) and included development of the Technical Approach and QAPP for the second phase. Additional work under Task Order 2 and 7 is expected to begin Ex. 5 Deliberative Process (DP) Given the need for USEPA review, public notice, comments, and responses, it is estimated that the modeling analysis and technical report must be completed by Ex. 5 Deliberative Process (DP) A detailed schedule will be developed as part of the Technical Direction for the next phase of the project.

SECTION XI: DATA MANAGEMENT

Tetra Tech will not conduct sampling (primary data collection) for this task. Secondary data collected as part of this task will be maintained as hardcopy only, both hardcopy and electronic, or electronic only, depending on their nature. All electronic data will be maintained on Tetra Tech's computers and servers.

Tetra Tech's computers are either covered by on-site service agreements or serviced by in-house specialists. When a problem with a microcomputer occurs, in-house computer specialists diagnose the problem and correct it if possible. When outside assistance is necessary, the computer specialists call the appropriate vendor. For other computer equipment requiring outside repair and not covered by a service contract, local computer service companies are used on a time-and-materials basis. Routine maintenance of microcomputers is performed by in-house computer specialists. Electric power to each microcomputer flows through a surge suppressor to protect electronic components from potentially damaging voltage spikes. All computer users have been instructed on the importance of routinely archiving work assignment data files from hard drive to compact disc or server storage. The office network server is backed up on tape nightly during the week. Screening for viruses on electronic files loaded on microcomputers or the network is standard company policy. Automated screening systems have been placed on all Tetra Tech computer systems and are updated regularly to ensure that viruses are identified and destroyed. Annual maintenance of software is performed to keep up with evolutionary changes in computer storage, media, and programs.

SECTION XII: RECORDKEEPING AND ARCHIVING

Thorough documentation of all modeling activities is necessary to be able to effectively interpret the results. All records and documents relevant to the application, including electronic versions of data and input data sets, will be maintained at Tetra Tech's offices in the central file. The central repository for the model will be Tetra Tech's Research Triangle Park, North Carolina, office. Tetra Tech will deliver a copy of the records and documents in the central file to USEPA at the end of the task. Unless other arrangements are made, records will be maintained at Tetra Tech's offices for a minimum of 3 years following task completion.

The Tetra Tech TOL, Technical Lead, and designees will maintain files, as appropriate, as repositories for information and data used in models and for preparing reports and documents during the task. Electronic project files are maintained on network computers and are backed up weekly. The Tetra Tech TOL and Technical Lead will supervise the use of materials in the central files. The following information will be included in the hard copy or electronic task files in the central file:

- Any reports and documents prepared
- Contract and task order information
- QAPP and draft and final versions of requirements and design documents
- Electronic copies of models
- Results of technical reviews, internal and external design tests, quality assessments of output data, and audits
- Documentation of response actions during the task to correct problems
- Input and test data sets

- Communications (memoranda; internal notes; telephone conversation records; letters; meeting minutes; and all written correspondence among the task team personnel, suppliers, or others)
- Studies, reports, documents, and newspaper articles pertaining to the task
- Special data compilations

Records of receipt with information on source and description of documentation will be filed along with the original data sheets and files to ensure traceability. Records of actions and subsequent findings will be kept during additional data processing.

All data files, source codes, and executable versions of the computer software will be retained for internal peer review, auditing, or post-task reuse in the electronic task files in the administrative record. These materials include the following:

- Versions of the source and executable code used
- Databases used for model input, as necessary
- Key assumptions
- Documentation of the model code and verification testing for newly developed codes or modifications to the existing model

The Tetra Tech Modeling QC Officer and other experienced technical staff will review the materials listed above during internal peer review of modified existing models or new codes or models. The designated QC Officers will perform QC checks on any modifications to the source code used in the design process. All new input and output files, together with existing files, records, codes, and data sets, will be saved for inspection and possible reuse.

SECTION XIII: QAPP REVIEW AND APPROVAL

The EPA TOCOR and Tetra Tech TOL and Technical Lead will lead distribution of the draft QAPP to their respective project teams. Comments from USEPA and relevant reviewers will be provided to the Tetra Tech TOL and Technical Lead for further discussion if appropriate, and revision and submittal of the final plan within 5 business days of receipt of comments. Following USEPA approval, the TOCOR and TOL and Technical Lead will distribute the final, signed copy to their respective staff assigned to the project. Official copies of the final, approved QAPP will be retained by the TOCOR and TOL. If any change(s) in the QAPP are required during the project, they must be described in a memorandum and approved by the signatories to this QAPP and attached to the QAPP.

SECTION XIV: IMPLEMENTATION AND ADAPTIVE MANAGEMENT

Tetra Tech understands that due to the complexity of model development, some elements of the project might not proceed according to plan. Should an obstacle arise that requires a change in approach, Tetra Tech, in consultation with the EPA TOCOR, will return to the QAPP as a topic template for evaluating the effects on other aspects of the project. Tetra Tech will update the QAPP as needed, through revisions or addenda, as model development proceeds and new aspects of the system are understood. Significant changes in technical approach would be described in the updated QAPP and would be reviewed by the project team listed on the QAPP approval page prior to implementation.

REFERENCES

Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr., A.S. Donigian Jr., and R.C. Johanson. 1997. Hydrological Simulation Program--Fortran, User's manual for version 11: U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, Ga., EPA/600/R-97/080, 755 p.

Bolks, A., A. DeWire, and J.B. Harcum. 2014. Baseline Assessment of Left-Censored Environmental Data Using R. Tech Notes 10. National Nonpoint Source Monitoring Program, U.S. Environmental Protection Agency.

Borselli, L., P. Cassi, and D. Torri. 2008. Prolegomena to sediment and flow connectivity in the landscape: A GIS and field numerical assessment. Catena, 75: 268-277.

Cavalli, M., S. Crema, and L. Marchi. 2014. Guidelines on the Sediment Connectivity ArcGIS 10.1 and 10.2 Toolbox. Release 1.1. CNR-IRPI Padova (PP4). Sediment Management in Alpine Basins (SedAlp).

Cavalli, M., S. Trevisani, F. Comiti, and L. Marchi. 2013. Geomorphometric assessment of spatial sediment connectivity in small Alpine catchments. *Geomorphology*, 188: 31-41.

Chapra, S.C., G. Pelletier, and H. Tao. 2012. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.12: Documentation and User Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

Cleland, B.R. 2002. TMDL development from the "bottom up" – Part II: Using load duration curves to connect the pieces. Proceedings from the WEF National TMDL Science and Policy 2002 Conference.

Cleland, B.R. 2003. TMDL development from the "bottom up" – Part III: Duration curves and wet-weather assessments. American's Clean Water Foundation, Washington, DC.

CREM. 2009. Guidance on the Development, Evaluation, and Application of Environmental Models. EPA/100/K-09/003. Office of the Science Advisor, Council for Regulatory Environmental Modeling, U.S. Environmental Protection Agency, Washington, DC.

Helsel, D. 2005. *Nondetects and Data Analysis, Statistics for Censored Environmental Data*. John Wiley & Sons, Hoboken, NJ.

Konovsky, J., and J. Puhn. 2005. Trends in Spawning Gravel Fine Sediment Levels – Deschutes River, Washington. Squaxin Island Tribe, Shelton, Washington.

Lee, L. 2017. Package 'NADA', Nondetects and Data Analysis for Censored Data. https://cran.rproject.org/web/packages/NADA/NADA.pdf, accessed 12/21/2017.

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, R. Srinivasan, and J.R. Williams. 2011. Soil and Water Assessment Tool, Input/Output File Documentation, Version 2009. TR-365. Texas Water Resources Institute, College Station, TX.

Packman, J.J., K.J. Comings, and D.B. Booth. 1999. Using turbidity to determine total suspended solids in urbanizing streams in the Puget Lowlands. *Confronting Uncertainty: Managing Change in*

Water Resources and the Environment, Canadian Water Resources Association Annual Meeting, Vancouver, BC, 27–29 October 1999, p. 158–165.

Pitt, R. 2004. Module 4: Erosion Mechanisms and the Revised Universal Soil Loss Equation (RUSLE). [HYPERLINK "http://unix.eng.ua.edu/~rpitt/Class/Erosioncontrol/Module3/Module4/Module4.pdf"], accessed 2/6/2019.

Raines, M. 2007. Deschutes River Mainstem Bank Erosion. 2007. Prepared for Squaxin Island Tribe Natural Resources Dept., Shelton, WA.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). Agricultural Handbook Number 703. U.S. Department of Agriculture. http://www.epa.gov/npdes/pubs/ruslech2.pdf.

Roberts, M., G. Pelletier, and A. Ahmed. 2015. Deschutes River, Capitol Lake, and Budd Inlet Total Maximum Daily Load Study, Supplemental Modeling Scenarios. Washington State Department of Ecology Publication No. 15-03-002. https://fortress.wa.gov/ecy/publications/SummaryPages/1503002.html

Roberts, M., A. Ahmed, G. Pelletier, and D. Osterberg. 2012. Deschutes River, Capitol Lake, and Budd Inlet Temperature, Fecal Coliform Bacteria, Dissolved Oxygen, pH, and Fine Sediment Total Maximum Daily Load Technical Report: Water Quality Study Findings. Washington State Department of Ecology Publication No. 12-03-008. https://fortress.wa.gov/ecy/publications/SummaryPages/1203008.html.

Schuett-Hames, D. and I. Child. 1996. An Assessment of Stream Temperature, Large Woody Debris Abundance and Spawning Gravel Fine Sediment Levels in the Mainstem Deschutes River. Squaxin Island Tribe, Shelton, WA.

Smith, R.A., Alexander, R.B., and G.E. Schwarz. 2003. Natural background concentrations of nutrients in streams and rivers of the conterminous United States. *Environmental Science & Technology,* 37(14): 3039-3047.

Stiles, T.C. 2002. Incorporating hydrology in determining TMDL endpoints and allocations. *Proceedings from the WEF National TMDL Science and Policy 2002 Conference*, Phoenix, AZ.

Stiles, T.C. 2001. A simple method to define bacteria TMDLs in Kansas. *ASIWPCA/ACWR/WEF TMDL Science Issues Conference: On-site Program*, St. Louis, MO, pp. 375-378.

Tetra Tech. 2016. Quality Management Plan for Technical Support for Assessment and Watershed Protection, EPA Contract Number EP-C-17-046. Prepared for U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds, Washington, DC.

Tetra Tech. 2018. Analysis of Washington Nutrient and Biological Data (Periphyton) for the Nutrient Scientific Technical Exchange Partnership Support (N-STEPS). Prepared for U.S. Environmental Protection Agency and Office of Water and Watersheds by Tetra Tech, Inc., Center for Ecological Sciences, Research Triangle Park, NC.

USEPA (U.S. Environmental Protection Agency). 1997. *Compendium of Tools for Watershed Assessment and TMDL Development.* EPA 841-B-97-006 . U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1999. *Protocol for Developing Sediment TMDLs.* EPA 841-B-99-004. Office of Water (4503F), United States Environmental Protection Agency, Washington D.C. 132 pp.

USEPA (U.S. Environmental Protection Agency). 2000. Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion II. EPA 822-B-00-015. U.S. Environmental Protection Agency, Office of Water, Washington, DC. [HYPERLINK "https://www.epa.gov/sites/production/files/documents/rivers2.pdf"]

USEPA (U.S. Environmental Protection Agency). 2001a. (reissued May 2006). Requirements for Quality Assurance Project Plans, EPA QA/R-5. EPA 240-B-01-003. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC. [HYPERLINK "http://www.epa.gov/quality/qs-docs/r5-final.pdf"]

USEPA (U.S. Environmental Protection Agency). 2001b. Protocol for Developing Pathogen TMDLs. EPA 841-R-00-002. Office of Water (4503F), United States Environmental Protection Agency, Washington D.C. 134 pp.

USEPA (U.S. Environmental Protection Agency). 2002. Guidance for Quality Assurance Project Plans for Modeling, EPA QA/G-5M. EPA/240/R-02/007. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2005. CIO Policy Transmittal 05-022, Classification No. 2121, Policy Title: EPA National Geospatial Data Policy. U.S. Environmental Protection Agency. [HYPERLINK "http://www.epa.gov/nerlesd1/gqc/pdf/epa_natl_geo_data_policy.pdf"]

USEPA (U.S. Environmental Protection Agency) 2007. CIO Policy Transmittal 08-004, Classification No. CIO 2131-P-01-0, Policy Title: EPA National Geospatial Data Policy Procedure for Geospatial Metadata Management. U.S. Environmental Protection Agency. [HYPERLINK "http://www.epa.gov/geospatial/docs/2131.pdf"]

USEPA (U.S. Environmental Protection Agency). 2009. Office of Water Quality Management Plan. EPA 821-R-09-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Vigiak, O., L. Borselli, L. Newham, J. McInnes, and A. Roberts. 2012. Comparison of conceptual landscape metrics to define hillslope-scale sediment delivery ratio. *Geomorphology*, 138(1):74–88.

Washington Forest Practices Board. 1997. Standard Methodology for Conducting Watershed Analysis. Washington State Department of Natural Resources. [HYPERLINK "http://www.dnr.wa.gov/BusinessPermits/Topics/ForestPracticesRules/Pages/fp_board_manual.aspx"].